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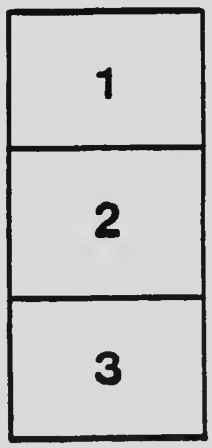
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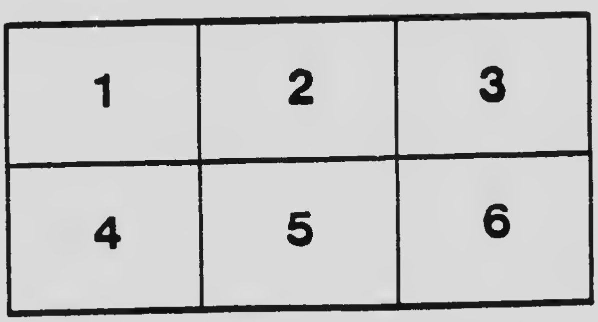
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GUIDE

TO THE

GEOLOGY OF THE CANADIAN NATIONAL PARKS

ON THE

Canadian Pacific Railway between Calgary and Revelstoke

BY

CHARLES CAMSELL

DEPARTMENT OF THE INTERIOR

HONOURABLE W. J. ROCHE
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INTRODUCTION

The material for this book is taken largely from the Guide Books written by D. B. Dowling, J. A. Allan and R. A. Daly for the the Excursions of the Twelfth International Geological Congress and published by the Geological Survey. For a more detailed and technical account of the geology of this region the reader should consult Part I and Part II of Guide Book No. 8. The author has endeavoured here to avoid as much as possible the use of technical language so that the text may read without difficulty by one who has only an elementary knowledge of geology.

Physical Features of the Canadian Cordillera.

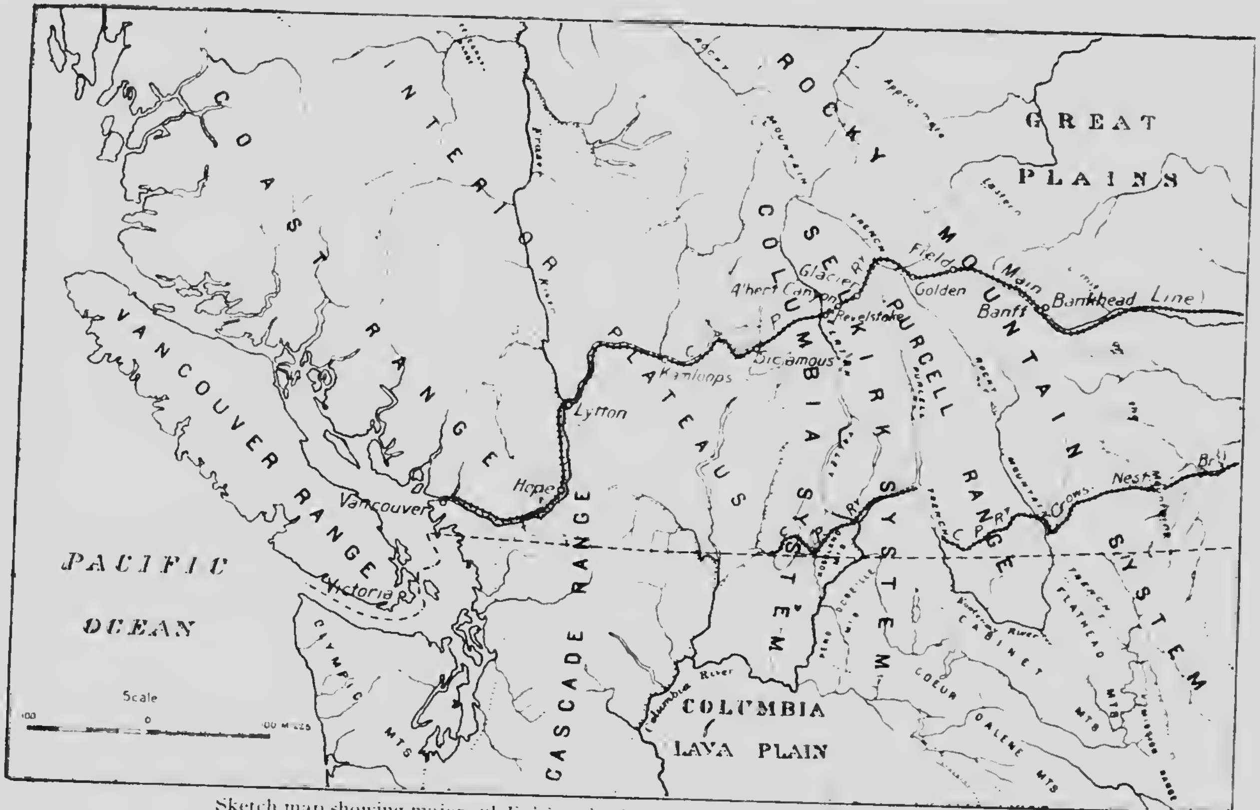
The North American Cordillera, or the series of mountain ranges, which extends without interruption from Panama to Behring sea, has a length of 4,350 miles and a width ranging from 300 to 1,000 miles and averaging about 560 miles. Its area therefore is about 2,300,000 square miles. The term Rocky Mountains is frequently applied in a loose way to this whole mountain region, but as is shown later it is more correct to restrict the application of this term to the first series of ranges in Canada that one meets on approaching the Cordillera from the east. This gigantic mountain chain has a north-westerly trend and because it has originated as a result of pressure exerted from the basin of the Pacific it borders that ocean from end to end and runs parallel to its coast line. In southern British Columbia about the latitude of the Canadian Pacific railway line the Cordillera has a width of about 435 miles, though along the somewhat tortuous route of the railway line the distance from the eastern foot of the mountains to the city of Victoria is about 650 miles.

For convenience in description it is necessary to sub-divide the Canadian Cordillera, along the section traversed by the Canadian Pacific railway, into its component parts, and among the various criteria for such sub-division the purely topographic principle used by Dr. G. M. Dawson seems to be the only practical one.

Using this principle and following in the main Dawson's classification, the Canadian Cordillera in this latitude may be broadly subdivided into 5 main provinces each of which is separated from the one next to it by topographic breaks of major importance.

These 5 provinces, from east to west, are as follows:—

(1) The Rocky Mountain system.
(2) The Interior ranges.
(3) The Interior Plateau region.
(4) The Coast-Cascade systems.
(5) The Vancouver system.



Sketch map showing major subdivisions in the southern part of the Canadian Cordillera.

The first, third, and fourth of these provinces extend, with only minor interruptions, throughout British Columbia and Yukon Territory into Alaska. The Interior ranges are specially broad in southern British Columbia but disappear to the north in Yukon Territory. To the south also they are broadly depressed and gradually merge into the lava plains of the States of Washington and Idaho. The last is confined to Vancouver Island.

As we are here only immediately concerned with the first two of these provinces, namely, the Rocky Mountain system and the Interior ranges, it will be convenient to refer at first briefly to the last three provinces and later to describe in more detail the first two.

The Vancouver system is the bordering range of the Canadian Cordillera, since beyond it, after a narrow submarine plateau, the sea bottom shelves off rapidly down to the abyssal depths of the Pacific. It is a mountain system partially submerged beneath the sea, of which the Queen Charlotte Islands form the northern unsubmerged extremity, and the Vancouver range the southern and main portion. The Vancouver range constitutes virtually the whole of Vancouver Island which is 290 miles long and 50 to 80 miles wide. It is separated from the Coast-Cascade systems to the east of it by a broad depression occupied by the waters of Puget sound, the Straits of Georgia and Queen Charlotte sound.

The Coast and Cascade systems are here grouped together though separated from each other by the great gorge in the mountains down which the Fraser river flows. The combined systems have a total length of about 1,500 miles and extend from Northern California through Oregon, Washington and British Columbia into Alaska. At the canyon of Fraser river the two systems overlap each other for about 100 miles and on the west of that stream the Coast range rises abruptly and extends northward along the coast for about 900 miles with an average width of about 100 miles. It is an exceedingly rugged range whose higher levels, though rarely exceeding 9,000 feet in elevation above the sea, are characterized by immense snow fields and magnificent glaciers which often descend directly into the sea.

The Coast and Cascade systems are bordered on the east by the Interior Plateau region into which they pass without any sharp topographic break. The Interior Plateau region has an average width of about 100 miles and extends from a short distance south of the International Boundary line northward through the central portion of British Columbia into the Yukon Territory, with however some break in its continuity near the British Columbia-Yukon boundary, where several rather high, broken ranges rise above the plateau level between the Coast and Rocky Mountain systems. Its average elevation is about 3,500 feet above the sea and when viewed broadly from elevations above this it is seen to have a gently undulating surface with rounded and generally wooded hills and nowhere any sharp or rugged peaks. It is however traversed by many deep trough-like valleys from the bottom of which one obtains the conception that the plateau is a distinctly mountainous region. On the east, as on the west, the Interior plateau region passes gradually on an upward slope into the alpine topography of the Interior ranges.

The two remaining provinces of the Canadian Cordillera are the Rocky Mountain system and the Interior ranges or as they were called by Dawson the Gold ranges. Since the region covered by this guide book lies entirely with these two provinces it will be necessary to describe them in greater detail and preferably in the order as they are approached by a traveller from the east.

The Rocky Mountain system forms the extreme eastern portion of the Cordillera and extends from the United States northward virtually to the Arctic ocean without any notable breaks except one at the Liard river and another at the Peel. In Southern British Columbia it has an average width of about 60 miles measured at right angles to its axis, though the diagonal course which the Canadian Pacific railway makes through it has a length of about 130 miles. The eastern border of the Rocky Mountain system here as well as throughout its whole length northward to the Arctic coast is the Great Plains. This border is not a sharp line of division but is marked usually by a belt of foot hills which in Southern Alberta is about 15 miles in width and which merges gradually on the one hand into the Great Plains region and more abruptly on the other hand into the main ranges of the Rockies.

On the west the Rocky Mountain system is bordered by a great long intramontane trough which is one of the most remarkable topographic features in the whole Cordillera. It extends in almost a direct line from Flathead lake in

Montana to the Yukon boundary line, a distance of nearly 1000 miles. The Canadian Pacific railway enters this master valley at Golden where it is occupied by the Columbia river. Southward of this point it is drained by the Columbia and Kootenay rivers, and to the north it is occupied successively by the Columbia and Canoe rivers, the Fraser, the Parsnip and Finlay of the Peace river system, and the Kachika of the Liard river system.

All the mountains east of the great valley as far as the Great Plains both in Canada and in Montana are considered as belonging to the Rocky Mountain system while the valley itself has been named the Rocky Mountain trench.

The Rocky Mountains are made up of a series of parallel ranges coinciding more or less closely in trend with the direction of the main mountain system. Between these ranges are deep longitudinal valleys whose positions have been determined by the existence of zones of softer rocks and which are occupied by the smaller streams. Crossing these ranges here and there at right angles are a series of transverse gaps through which the major streams which rise far back in the interior ranges break through to the Great Plains on the one hand or the Rocky Mountain trench on the other.

The resulting pattern produced by the drainage is that of a series of oblong, rectangular blocks the longer lines of which strike northwest and southeast parallel to the trend of the mountains, and the shorter lines northeast and southwest at right angles to this trend. This pattern is very evident in the valleys of the Bow and Kicking Horse rivers which are followed by the railway line. It is directly connected with the origin of the mountains themselves. The longitudinal valleys are believed to be the result of the pressure exerted from a direction at right angles to these axes, namely, from the Pacific, by which the strata have been thrust up into a series of long parallel folds striking northwest and southeast. In the central part of the Rockies the thrust has been so great that the folds of the strata have actually been overturned toward the east, while in the foot-hills region where the force of the thrust has been less the folds are more open. Valleys resulting from such a cause might be either of two kinds, namely, valleys of depression which coincide with troughs in the strata, or valleys of erosion which have been carved out by the streams along the strike of the softer beds, or along lines of weakness or dislocation. The latter are the prevailing type, both here and in other mountainous regions. The cause of the transverse valleys is not always evident and it is a question to be decided in each individual case whether the transverse breaks are due to erosion by the streams along lines of fracturing and shattering of the rocks, or whether they represent portions of the older river valleys which existed previous to the elevation of the mountain ranges—and which were able to maintain their courses against the slow and gradual elevation of the strata in the mountain building period.

The transverse valleys are always short in comparison to the longitudinal valleys and in no case in this region does a transverse break preserve its character so definitely across the whole breadth of the range as to form a direct pass. The routes of travel therefore follow zig-zag courses partly along the longitudinal valleys, and the length of the various passes are usually considerably greater than the actual width of the mountains.

The Kicking Horse pass, by which the railway line crosses the mountains, is typical of these mountain passes. The actual pass itself and the upper part of the valley of Kicking Horse river is a transverse valley. Bow river however from above Laggan down to Sawback occupies a longitudinal valley, that has been cut down by the stream into and along the crest of a fold in the strata. It is therefore here an anticlinal valley. From Sawback to Bankhead it turns eastward and occupies a transverse break across the strike of the Sawback range. It then reaches a belt of soft rocks which deflects its course again south eastward down a longitudinal valley until below Canmore it turns at right angles and breaks through the outer ranges into the foot-hills.

The transverse portions of the Bow as well as of other valleys are supposed to be geologically the most ancient valleys as they are those for which least apparent cause can be found at the present day. They are believed to be the parts of very old river valleys which existed previous to the elevation of the mountains, and as these mountains were elevated, not suddenly in one gigantic catalysm, but gradually during a period covering possibly millions of years, the streams were able to cut down their beds at the same rate that the rocks were being elevated, and so preserved their courses. It is highly probable that the valley in which Minnewanka lake now lies was once occupied by the Bow river which then flowed through the mountains by way of the Devil's Gap. The change in its course probably took place during or at the close of the Glacial period when Minnewanka lake valley may have become blocked by glacier ice from the high mountains surrounding it.

In the vicinity of the railway line the loftiest summits are those in the Bow range about the main divide where several individual peaks rise above 11,000 feet in elevation. A number of mountains exceed 10,000 feet in height, while whole ranges and groups of peaks surpass 8,000 feet.

The type of mountain most commonly developed particularly on the east slope of the mountains is that of the escarpment with a steep slope on one side and a longer, easy slope on the other. The steep slopes generally face eastward while the longer slopes are on the west side. This feature again, like that of the longitudinal valleys, can be attributed primarily to the elevation of the mountains by thrust from the west, the strata having been folded and overturned, or broken and overthrust, on each other. Erosion then produces the steep eastern slope, while the easy western slope represents the original dip of the strata. Where the mountain tops are composed of nearly horizontal beds of massive limestones, as they often are, the easy breaking up of the beds along joint planes at right angles to the bedding produces summits of striking forms of which the upper parts are almost sheer cliffs. This castellated or rampart-like form is well illustrated in Castle Mountain. A later stage in decay of mountains of this type produces chimney or spire-like peaks. Where the limestone beds have been turned completely on edge, as in the Sawback range, the massive character is replaced by straight narrow crests and saw-like outlines.

Patches of perennial snow may be frequently seen at elevations about 6,000 feet, and in retired valleys and on northern slopes of the higher ranges true glaciers occur.

Lakes are not numerous or large but are remarkable for the clearness of their water and the beauty of their surroundings. The majority of these owe their origin to glacial causes, some of them being formed by the damming of valleys by morainal material, while others occupy cirques which have been gouged out of the solid rock by valley glaciers.

The Interior ranges along the line of the Canadian Pacific comprise three groups of mountains, namely, the Purcell, Selkirk and Columbia systems. The Selkirk is the only mountain system which comes entirely within the scope of this guide as the Purcell system lies to the south of the railway line and is not crossed by it, while the Columbia system lies to the west of the region described.

The Purcell mountain system rises south of the International Boundary line and has its northern termination in the Columbia valley between Golden and Beavermouth. Throughout its whole length it lies on the western side of the great Columbia-Kootenay valley, or Rocky Mountain trench, and is bordered on the west by another deep valley which is occupied by the Beaver and Duncan rivers and Kootenay lake, a valley which has been named by R. A. Daly, the Purcell trench. In general the character of the Purcell system is much more irregular and confused than that of the Rockies. This difference is due to the difference in the nature of the rocks of which they are built, for while the Rockies are built of stratified sedimentary rocks, the Purcells are made up, in the southern part at least, of massive granites and schists, which do not as a rule give rise to parallelism in its constituent ranges.

The Selkirk mountain system occupies the loop in the great bend of the Columbia river and lies between the Purcell and Columbia mountain systems.

The boundary between the Columbia and Selkirk mountain systems is the valley of Arrow lakes and the Columbia river northward to the great bend. The Columbia system, or as it has frequently been called, the Gold range, is about 60 miles in width and on the west is bounded by the Interior Plateau region into which it passes by an easy and gradual transition. It extends southward into the United States and northward into the central part of British Columbia under the name of the Cariboo Mountains.

The Selkirk mountains where crossed by the Canadian Pacific have a straight line width of nearly 40 miles, though the course followed by the railway has a length of 65 miles. The limit of the system to the south has not been definitely defined, and by some writers is made to extend down to the Columbia lava plain. This would give it a length of about 400 miles. Its northern extremity is at the big bend of the Columbia river.

The Selkirks rise abruptly from the valley of the Columbia river to a broad, irregular region of sharp peaks and snow covered slopes, which culminates in the back bone of the range in summits which occasionally exceed 10,000 feet in height. The valley of the Columbia river at Revelstoke is 1,500 feet above sea level so that there is a vertical range of relief in the Selkirks of 8,500 feet.

The contour of the range is much more massive than that of the Rockies and the assemblage of peaks show no arrangement along definite lines. This is probably due partly to difference in the character of the rocks and the greater age of the mountains. The streams draining the range are mostly glacier-fed and are short and rapid. They occupy rather narrow V-shaped valleys in which are many sharper canyons and falls. Lakes are not numerous. Below the snow line, especially on the western side, the slopes are densely forested and on the higher levels are enormous glaciers and wide snow fields. In scenery the Selkirks are grand beyond description and much of the range still remains that has never been seen by human eye.

THE BUILDING OF THE MOUNTAINS.

Since no one has ever seen mountain ranges in actual process of formation the manner in which they are built must be deduced from a study of their structure.

The Rocky Mountains and the Selkirks along the railway line are built out of thick series of sedimentary strata which must have been laid down originally one on top of the other in the sea in a horizontal or approximately horizontal attitude. The first step in the formation of the mountains then was the accumulation of these sediments in a sea which covered the present site of the mountains, and the floor of which was gradually subsiding. The position of this sea was determined as far back as the Cambrian period, and from that time down to the end of Cretaceous it received sedimentary material mainly from a land area on the west until a thickness of over 50,000 feet of material was laid down and afterwards consolidated into rock.

The second stage in the building of the mountains was the upheaval of this thick mass of strata into a series of parallel folds striking slightly west of north. This was produced by lateral compression directed from the Pacific side and acting very slowly but with enormous force. As the compressing force increased the folds were arched higher and became more tightly crowded together until they were either overturned, or broken and thrust one over the other towards the east. The greatest disturbance in the strata of the Rocky Mountains appears to be in the eastern ranges and as one goes eastward to the prairies this disturbance decreases until it dies out altogether.

The elevation of the Rockies is believed to have taken place at the beginning of the Tertiary period. Its subsequent history is a record of erosion and denudation.

The mountains are not now in the shape that they would have been left if upheaval had been the only agent concerned in their formation. But it is evident that their ridges, peaks, and valleys have been carved out of other forms by the agencies of denudation.

As upheaval is a slow process, denudation must have begun its work as soon as the crests of the folds made their appearance above the sea, so that the mountain probably never had the full height which the strata, if free from denudation, would have given them.

The agents of denudation are running water, frost, wind and glaciers, and by these the ridges are carved into various shapes, valleys eroded out, and a general destruction of the ranges is carried out. For a long time the effect of denudation is to increase the ruggedness of the mountains and this is the stage at which the history of the Rocky Mountains now is. As time goes on however they will be worn lower and lower until they are eventually reduced to the level of the plains. Geologically speaking the wearing down of a mountain range to the level of the plain takes place in a comparatively short time, but from a human point of view the process is exceedingly slow.

GLACIATION.

During the Glacial period the Canadian Cordillera is believed to have been covered by an ice cap much as that which covers Greenland or the Antarctic continent at the present day. Through this ice cap only the higher peaks of the mountain ranges projected. The evidence that has been obtained by a study of the record left by this ice cap shows that it extended from the 48th to the 63rd parallels of latitude or a distance of about 1,200 miles and covered the region from the Rockies to the Coast range. During its height valley glaciers flowed eastward through gaps in the Rocky mountains to the Great Plains and westward through other gaps in the Coast range to the Pacific, though in consequence of these high bordering mountain ranges the greater part of the ice was forced to follow the direction of the ranges and flow northward in the northern part and southward in its southern part.

Elevation of the whole Canadian Cordilleran region above the level that it now has is believed to have been one of the causes at least which brought on the conditions of a glacial period. Other causes by which the whole northern hemsphere was affected are believed to have acted concurrently with this. These causes may have been one of several, namely, a change in the position of the earth's axis, change in the eccentricity of the earth's orbit, or some other cause. Whatever the cause the Canadian Cordillera appears to have become at this time the condenser of the moisture from the Pacific. Precipitation occurred upon it mainly in the form of snow and was so much in excess of the influence of the heat of the summer that the snow was not melted, but accumulated from year to year. Glaciers probably formed first in the higher mountains of the Coast range, but eventually almost the whole of the region became covered and buried beneath glacier ice. The direction of the ice flow was first along the valleys, but at a later date when the Cordillera became completely buried, a general movement northward as well as southward was started from a central point about the heads waters of the Stikine and Skeena rivers.

Over a great part of the region the surface of the ice cap stood at a level of about 7,000 feet above the sea. The thickness of the ice sheet over such deep valleys as Okanagan and Columbia must have been therefore 5500 to 6,000 feet.

Notwithstanding its great size the main ice cap, because of its slow rate of movement, was not as active an agent for the erosion of the rocks as the more swiftly-moving valley glaciers. It was however active enough to erode and carry away the decomposed and disintegrated surface of the bed rock and deposit this material on its outer edges as terminal moraines. Its traces are to be seen in the rounding, smoothing, and striation of rock knobs and a general levelling of the surface, by erosion as well as by filling up of hollows and irregularities.

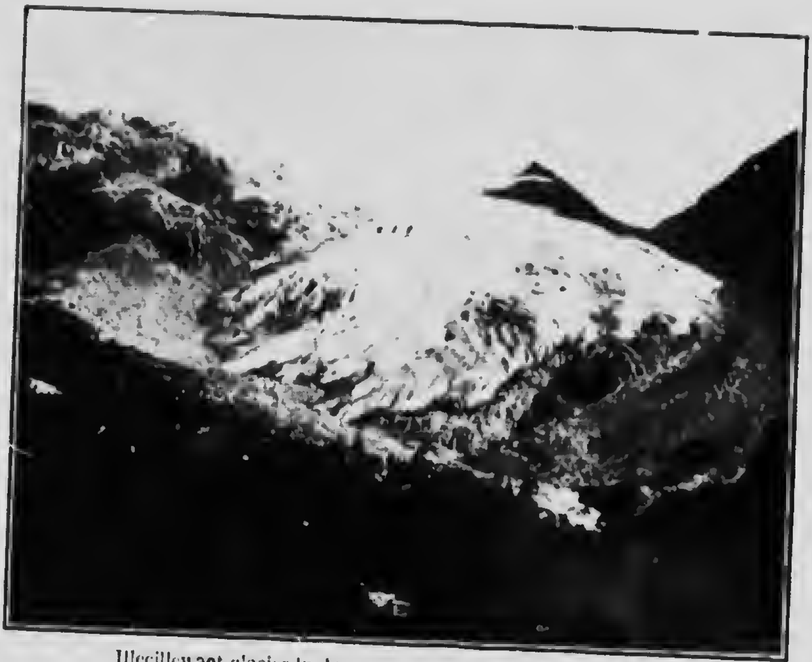
The valley glaciers on the other hand were more active as eroding agents, both because of their more rapid movement and their occupying lines of more concentrated flow. By the aid of rock fragments carried along the bottom of the glaciers they were able to broaden and deepen to valleys, and by this means to produce hanging valleys in the tributaries of a main valley, and to gouge out the cirques which are now occupied by those many beautiful rock-bound lakes so common throughout the Cordillera.

There is at present not sufficient evidence to prove that there was more than one general period of glaciation. It is certain that there was one, but it is not likely that in this one the ice gradually accumulated till it reached a maximum and then gradually decreased down to the present condition. It is evident, however, that in this general period there were oscillations of the ice fronts as a result of alternating increase and decrease of glacial conditions.

The present day glaciers, which lie at the head of many of the valleys, both in the Rockies and the Selkirks, are merely the shrunken remnants of the greater glaciers of the Glacial period.

From observations that have been made within the last 20 years on the condition of some of the Glaciers in the Selkirks it is certain that they have retreated some distance during that time. The length of time over which these observations have been made and even since the glaciers were first discovered, however, is so short in comparison to the length of time that has elapsed since the Glacial period was at its maximum that it is unsafe to base any general conclusions as to the stage at which the ice now is, that is to say whether the climate conditions of this part of the earth are advancing toward or retreating from a period of glaciation.

Not a great deal has been done since the final disappearance of the ice sheet to modify the shape of the land surface as left by it. The most striking changes have been affected by the rivers in cutting down their valleys through the glacial deposits left in them on the retreat of the ice. In the deepening of the valleys by the rivers since glacial times terraces have been formed on either side to mark different stages in the progress of that deepening.



Illecillewaet glacier in August, 1911. Photograph by H. Ries.

Illecillewaet glacier in August, 1912. Comparison with the preceding figure shows recession of the ice-front during the year preceding. Photograph by H. Ries.

DESCRIPTION OF ROCK FORMATIONS.

STRATIGRAPHY.

The straitigraphy of a region includes the mode of occurrence, order of succession, and general geological characters of the stratified rocks of which that region is composed. The stratified rocks are deposits laid down mainly in the sea but sometimes on land, and unless they have been overturned during periods of mountain building their sequence from bottom to top represents their relative ages, the bottom beds being older than those that overlie them. Their actual age in geological time is in the main determined by the fossil remains of animal and plant life which they contain.

The section of the stratified rocks exposed along the line of the Canadian Pacific railway contains an almost complete history of the whole Cordillera from the earliest times down to the present. Practically the whole geological column from Archean to Recent is represented in one part or the other of the section by some rock member. The only formations that fail to appear are the Pliocene and the Miocene, and it is possible that some of the formations attributed to the Oligocene may be really Miocene. The whole sequence does not occur in any one place but by obtaining a part here and another part there along the line of the railway and correlating one with the other the whole succession can be worked out.

The completeness of the section can be explained mainly by upturning of the strata and exposure of some of the older underlying beds, which without that elevation would have remained covered and unknown. Both in the Selkirks and the Rockies elevation of the earth's crust has brought up the various beds to a point where they became subject to the eroding action of water and the atmosphere, and the younger of the beds have been worn away exposing the older beds to view.

The total thickness of the stratified rocks of the section is 135,000 feet measured at right angles to their bedding planes. Of this thickness 25,000 feet are volcanic beds, while the remainder is sedimentary in origin.

In the succeeding table the main formations, as exposed along the line of the Canadian Pacific railway, are given in chronological sequence from youngest to oldest with their thicknesses.

GEOLOGICAL TABLE FOR THE CANADIAN CORDILLERA.

GEOLOGICAL TABLE FOR THE CANADIAN CORDILLERA.

Time in years, after J. D. Dana.	Eras.	Ages.	Periods.	Formations, after R. A. Daly.
30,000	Psychozoic	Age of Man	Human	
3,000,000	Cenozoic	Age of Mammals	Quaternary—Recent	Soil.
			Pleistocene	Lake, river, and glacial deposits.
				—Unconformity—
			Tertiary—Pliocene.	
			Miocene.	
			Oligocene	Kamloops volcanic group (?). 3,000 ft.
				Tranquille beds (?). 1,000 ft.
				Unconformity—
			Eocene	Coldwater group. 5,000 ft.
				Puget group.
				Ashcroft rhyolite, porphyry.
				—Unconformity—
9,000,000	Mesozoic	Age of Reptiles	Cretaceous—Upper.	
			Lower	Jackass Mt. group.
				Upper Ribboned sandstone, 550 ft.
				Kootenay Coal measures, 2,800 ft.
				Lower Ribboned sandstone, 1,000 ft.
				Spence's Bridge volcanic group.
			Jurassic	Fernie shale, 1,500 ft.
				Nicola group (upper part).
			Triassic	Nicola group (lower part), 10,000 ft.
				—Unconformity—
30,000,000	Paleozoic	Age of Amphibians	Permian	Upper Banff shale, 1,400 ft.
			Carboniferous—Pennsylvanian.	Rocky Mt. quartzite, 800 ft.
				Upper Banff Limestone, 2,300 ft.
				Cache Creek group, 9,500 ft.
			Mississippian [illegible]	[illegible]

30,000,000	Paleozoic......	Age of Amphibians...	Permian......	Upper Banff shale, 1,400 ft.
			Carboniferous—Pennsylvanian.	Rocky Mt. quartzite, 800 ft.
				Upper Banff Limestone, 2,390 ft.
				Cache Creek group, 9,500 ft...
			Mississippian...	Lower Banff shale, 1,200 ft.
				Lower Banff limestone, partly Devonian, 1,500 ft.
		Age of Fishes....	Devonian....	Intermediate limestone, 1,800 ft.
				Sawback limestone, 3,700 ft.
		Age of Invertebrates....	Silurian...	Halysites beds, 1,850 ft.
				Goodsir shale, 6,040 ft.
			Ordovician.....	Graptolite shale, 1,700 ft.
			Cambrian Upper....	Ottertail limestone, 1,725 ft.
				Chancellor shales, 4,500 ft.
				Sherbrooke Limestones, 1,375 ft.
				Paget limestones, 360 ft.
				Bosworth limestones, 1,855 ft.
			Middle.........	Eldon Limestones, 2,728 ft.
				Stephen limestones-shale, 640 ft.
				Cathedral limestones, 1595 ft.
			Lower.........	Mt. Whyte sandstone-shale, 390 ft.
				St. Piran quartzite, 2,705 ft.
				Lake Louise shale, 105 ft.
				Fairview sandstone, 600 ft.
				(Sir Donald quartzite, 5,000 ft.
				Ross quartzite, upper part, 2,750 ft. in Selkirk Mts.)
				—Local Unconformity in Rockies—
(?)	Proterozoic...		Beltian...	Ross quartzite (lower part), 2,500 ft.
				Nakimu limestone, 350 ft.
				Cougar quartzites, 10,800 ft.
				Laurie metargillites, 15,000 ft
				Illecillewaet quartzite, 1,500 ft.
				Moose metargillite, 2,150 ft.
				Limestone, 170 ft.
				Basal quartzite, 280 ft.
				Unconformity —
(?)	Archeozoic.	Life not yet known to exist	Pre-Beltian (Shuswap series)..	Adams lake greenstones, 10,000 ft.
				Tshinakin limestone-quartzite, 3,900 ft.
				Bastion schists, 6,500 ft.
				Sicamous limestones, 3,200 ft.
				Salmon Arm mica schists, 1,800 ft.
				Chase quartzite, 3,000 ft.
				Tonkawatla paragneiss, 1,500 ft
				Base not exposed.

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This table of formations contains merely the stratified rocks, sedimentary and volcanic. Plutonic and intrusive igneous rocks are not included, though they are present, in the section. Igneous activity, accompanied by the intrusion of igneous rocks in the form of large batholiths and smaller dykes, took place in the pre-Beltian, Beltian, Paleozoic, Mesozoic and Cenozoic Eras.

In order to thoroughly understand the description of the rock formations that follows, the reader should first of all study carefully the geological table here inserted and should at least be familiar with the sequence and relative positions of the geological periods in the fourth column. Unless this is done much of what follows will be quite unintelligible to him.

PRE-BELTIAN OR SHUSWAP.

The oldest rocks in which recognizable fossils occur in this part of America are the Beltian; but beneath them is a still more ancient series of rocks in which no sign of life has yet been found, and which form a part of the most ancient rock series of which we have any certain knowledge. Here in British Columbia these rocks are called the Shuswap series because of their having been first described by Dawson from Shuswap lake. In other parts of America they are known as Archean, or pre-Cambrian. They belong to an era which is sometimes called Azoic to indicate the absence of any life, but since they may yet be shown to contain fossils a better term is Archeozoic.

The Shuswap rocks form the foundation on which all the younger rocks of British Columbia were laid down and from which most of them were later derived. They form part of the most ancient series of rocks in the crust of the earth, which though covered in most places by layers of younger rocks have here become exposed by elevation and later denudation of the cover. They consist of a very thick series of bedded rocks and a younger group of igneous rocks that have been intruded into the bedded rocks, the whole making a complex of very variable composition.

The Shuswap series is best exposed on the shores of Shuswap and Adams lake, but it also occurs along the line of railway from Albert Canyon almost to Salmon Arm and again between Tappen and Shuswap stations. It consists limestones, quartzites, schists, argillites or metamorphosed clay rocks, green-stones, and gneisses. It includes therefore both water laid sediments and volcanic flows, indicating that in the sea in which the sediments were being deposited volcanic activity frequently broke out with outpourings of lavas.

Intrusive igneous rocks are also very abundant, which both cross-cut the beds of the stratified rocks and have been injected in the form of sills or sheets along the planes of bedding. The igneous rocks are mainly granites while the dykes and sills are fine or coarse grained offshoots from the granite. These igneous rocks are so numerous throughout the Shuswap series as to suggest a large body of molten granitic material underneath the stratified rocks, into which this material rose in a molten fluid state through fissures to form the dykes, sills and other kinds of eruptive bodies that are now found in them.

The total thickness of Shuswap rocks exposed along the line of the railway is nearly 30,000 feet, but as the base of the series is not exposed it is impossible to say how much thicker these rocks actually are.

The following is Daly's section as exposed along the line of railway:—

TOP. EROSION SURFACE.	THICKNESS.
Adams Lake formation; greenstone schists....	1,000 feet.
Tshinakin formation:	
Limestone (1,500 ft.)....	
Phyllitic metargillite (800 ft.)	
Limestone (1,600 ft.)	
Total..........................	3,900 "
Bastion schists, phyllite with green schists at top..............................	6,500 "
Sicamous limestone........................	3,200 "
Salmon Arm schists, micaceous............	1,800 "
Chase quartzite..........................	3,000 "
Tonkawatla paragneiss....................	1,500 + "
Base concealed	
Total......................	29,900

The Shuswap series, though the oldest of the rock formations of the mountains, has not been seriously disturbed and its beds have not been tilted at high angles. The average dip of its beds is about 35 degrees. During the later geologic periods of revolution and disturbance where the strata of the Selkirks and Rockies were folded and elevated into mountain ranges the Shuswap series remained practically undisturbed. In those periods it was either too rigid to be folded or else it was so deeply buried by other strata that have since been worn off its surface as to be below the zone of crumpling and disturbance. The series however is highly altered, and by this alteration its sandstones have become quartzites; its clay rocks have become argillites or very thinly laminated phyllites; its volcanic flows have become green schists, and its other rocks have been fractured and sheared and altered either to schists or gneisses. Some of the alteration is regional and due to lateral pressure and thrust in periods of disturbance and mountain building. Much of it is due to the intrusion of molten igneous rocks, but this is confined to the borders of the igneous rocks. A much graeter alteration however has been effected in the Shuswap rocks by their burial far down beneath a load of overlying rocks, and by the dead weight of these rocks on top of them.

BELTIAN.

The Beltian, which Daly makes to include Dawson's Selkirk series as well as his Nisconlith series, is the next younger series to the Shuswap.

Rocks of Beltian age form the greater part of the section through the Selkirk mountains from the Columbia valley to Albert Canyon, and they occur also as the Corral Creek and Hector formations in the Rockies along either side of the valley of Bow river from Castle Mountain to the head waters of Bow river.

The thickness of Beltian rocks as exposed in the Selkirks is enormous and according to Daly is 32,750 feet even with the top portion eroded away. It is made up of the following members:—

Top of Cougar mountain, looking southeast; showing Cougar quartzite as typically developed in the Selkirk range.

Columnar Section of the Beltian System in the Selkirk Mountains.

Division	Top, erosion surface	Approximate Thickness. Feet.
Glacier Division (Selkirk series of Dawson).	Ross quartzite (in part) ..	2,500
	Nakimu limestone	350
	Cougar formation (quartzite with metargillitic beds)....	10,800
Albert Canyon Division (Nisconlith series of Dawson).	Laurie formation (metargillite, often calcareous; with subordinate interbeds of limestone and quartzite; basal bed, gray limestone 36 ft. thick).	15,000
	Illecillewaet quartzite....	1,500
	Moose metargillite...	2,150
	Limestone (marble	170
	Basal quartzite ..	280
Base, unconformity with Shuswap terrane.		
		32,750

In the Rockies the exposed thickness of the Beltian, according to J. A. Allan, is 5,910 feet, of which the Corral Creek formation is 1,320 feet, with the bottom part not exposed, and the Hector formation 4,590 feet. The Corral Creek beds are the oldest rocks exposed in the Rocky Mountain section, and they outcrop in a railway cut 2 miles east of Laggan. They consist of gray sandstones which pass downward at the base into a conglomerate. The Hector formation is best exposed in the Bow range east of Storm Mountain. It consists of gray, purplish, and greenish shales interbedded with bands of conglomerate 45 to 230 feet thick. Obscure fossils are found in the upper part of the formation on the eastern base of Storm Mountain.

The Beltian rocks contain the first evidence of life to be found in rocks of the earth's crust. This is contained in the fossils that have been preserved in them.

The first appearance of life is an event which exceeds in interest any later changes in the form and structure of living things. Life is believed to have been present in the Archeozoic era but the evidence for this is indirect as no fossils have yet been found in it. In the Proterozoic era

Contact of the Pre-Cambrian shales (Hector) and the Lower Cambrian quartzites. Exposed in Bath creek west of Laggan.

(Beltian) the first fossils found are those of comparatively highly developed animals, brachiopods and, later, crustaceans, and this fact justifies us in believing that, if higher types are the result of the evolution of lower, some life had already been in existence the records of which have been destroyed or are not yet found in the older rocks.

The Beltian strata were laid down in a broad area of depression or synclinal basin covered by water, which had the Shuswap land surface on the west and another land surface to the east of the Rockies. Their material was derived from the erosion and wearing down of these two land areas and carried into the depression by streams flowing into it. They were later covered by other sediments and later still elevated and folded in mountain ranges so that in their present attitude they dip at comparatively high angles especially in the Rockies. In the process of mountain building the rocks were also compressed, fractured, faulted and altered. The compression is evident in the case of the Nakimu limestone, in which are the Caves of Cheops, where the limestone bulges to abnormal thickness and in other places has been squeezed to a thin band.

CAMBRIAN.

In the Selkirk mountains the rocks of Beltian age pass gradually into the Cambrian rocks without any break, showing that in this part there was no interruption in the progress of sedimentation. In the Rockies however there is some evidence of a break between the two rock systems suggesting a lapse of time between the completion of Beltian sedimentation and the beginning of Cambrian deposition. How great this time break is it is hard to say.

Like the Beltian, the Cambrian rocks were laid down in a down warped or synclinal basin occupied by a broad interior sea, which is believed to have been connected on the north with the Arctic ocean and on the south with the Pacific in southern California, but in southern British Columbia was separated from the Pacific by a land area some hundreds of miles in width which extended westward from the Columbia mountains. This interior sea covered the present position of the Selkirk and Rocky Mountains

Drag folds in the Cougar quartzite near head of Cougar creek, Selkirk range.
Cliff shown is about 50 feet in height.

and persisted in that position throughout succeeding ages almost without interruption down to the beginning of the Tertiary period.

In the Selkirk mountains the Cambrian is represented by the Sir Donald quartzite and the upper part of the Ross quartzite. These rocks are exposed on the summit of Rogers pass and at the mouth of Beaver river. The Sir Donald quartzite forms most of the higher summits of the Selkirk mountains. Upper Cambrian rocks occupy the

Summit of Mt. Tupper from Tupper Crest, showing characteristic habit of the Sir Donald Quartzite. Photograph by Howard Palmer.

valley of Columbia river, where they have been faulted downward by a great fault running parallel with the valley.

The Cambrian portion of the Ross quartzite is about 2,750 feet thick and is equivalent to the Fairview formation in the Rockies. It is in general a thick bedded, rusty, altered sandstone, which grades without any sharp break into the Sir Donald quartzite. The Sir Donald quartzite is 5,000 feet thick and is also thick-bedded and homogeneous, but weathers gray instead of rusty. It is equivalent to the Lake Louise, St. Piran and Mt. Whyte formations of the Rockies. No fossils have been found in either the Ross or Sir Donald formations, but from their relative position in the section they are clearly Lower Cambrian in age. These are the youngest rocks found in this part of the Selkirk mountains and though they were probably at one time covered by younger strata, these strata have been worn away in the course of ages.

In the Rocky Mountains the Cambrian section is complete from top to bottom with a total thickness of over 18,000 feet of beds. This represents one of the thickest Cambrian sections yet measured in the world. They form the backbone of the Rocky Mountains and are exposed along the line of railway from Stephen to Leanchoil.

The following table gives the divisions of the Cambrian and their characters in this section:—

COLUMNAR SECTION of the Rocky Mountain Cambrian

	Formation.	Thickness.	Character.
		Feet.	
Upper Cambrian...	Ottertail..	1,725	Massive blue limestones with cherty and shaly bands.
	Chancellor...	1,500	Thinly laminated, gray argillaceous and calcareous Meta-argillites and shales, weathering reddish, yellowish and fawn; underlain by highly sheared, gray shales, slates, argillites and phyllites in Ottertail valley.
	Sherbrooke....	1,375	Thin-bedded, oolitic, arenaceous or dolomitic limestone.
	Paget......	360	Massive, bluish gray limestones, with oolitic bands of dolomitic limestone.
	Bosworth...	1,855	Massive, gray, arenaceous and dolomitic limestone, weathering yellowish buff, interbedded with greenish siliceous shale, weathering red, yellow and purple.
Middle Cambrian	Eldon....	2,728	Massive-bedded, arenaceous limestones forming cliffs and castellated crags.
	Stephen	640	Thin-bedded limestone, and shale; includes "Ogygopsis Shale" in Mt. Stephen and "Burgess shale" in Mt. Field.
	Cathedral....	1,595	Thin-bedded, arenaceous and dolomitic limestones.
Lower Cambrian...	Mt. Whyte..	390	Siliceous shale, sandstone and thin-bedded limestone.
	St. Piran..	2,705	Ferruginous quartzitic sandstone.
	Lake Louise..	105	Compact, grayish, siliceous slate.
	Fairview....	600	Ferruginous, quartzitic sandstone. Local basal conglomerate and coarse-grained sandstone.
		18,578 ft	

The Rocky Mountain Lower Cambrian consists essentially of quartzitic sandstones and siliceous shales, with a total thickness of 3,800 feet. It occupies the western slope of Bow valley and is well exposed at Lake Louise and Stephen. It also forms the base of the north slope of Mount Stephen and is the formation in which the spiral tunnels near Field are driven. It contains the records of animal life in the marks of borings of annelids or worms.

The character of the Lower Cambrian sandstones and shales suggests that they were laid down when the interior sea was shallow; but in Middle Cambrian times this sea began to deepen and deposits characteristic of deeper water were laid down. The Middle Cambrian therefore is represented mainly by beds of limestone with only a subordinate amount of shale. The total thickness of the strata is nearly 5,000 feet. They occur mainly on the upper part of Kicking Horse river, especially on the north side, and are characteristically developed in Mts. Stephen and Cathedral. The Eldon formation in particular is easily recognized by forming steep-sided, castellated mountains, and it is this formation that gives Castle Mountain its striking appearance.

The Middle Cambrian contains many remains of animal life especially in the Stephen formation. The famous "Ogygopsis shale" on Mt. Stephen and the "Burgess Shale" on Mt. Field on the opposite side of the valley have been found by Dr. Walcott to contain a great variety of Trilobites, Pteropods, Brachiopods, Annelids and sponges. Trilobites are specially abundant and indeed more highly developed than their modern representative the crab.

Approximately the same conditions persisted through the Upper Cambrian as existed in the Middle Cambrian so that the rocks formed during the Upper Cambrian consist mainly of limestones and some shales. The Upper Cambrian includes the Bosworth, Paget, Sherbrooke, Chancellor and Ottertail formations with a total thickness of 9,815 feet. The Bosworth, Paget and Sherbrooke formations are all limestones and are best developed on Mt. Bosworth north of Hector. The Chancellor consist essentially of shales which weather reddish, yellowish or fawn colored. They cover the floor of Ottertail valley and make up a great part of the Van Horne range. The Ottertail formation is a massive blue limestone which is rather thin bedded at the base. It is well exposed in an

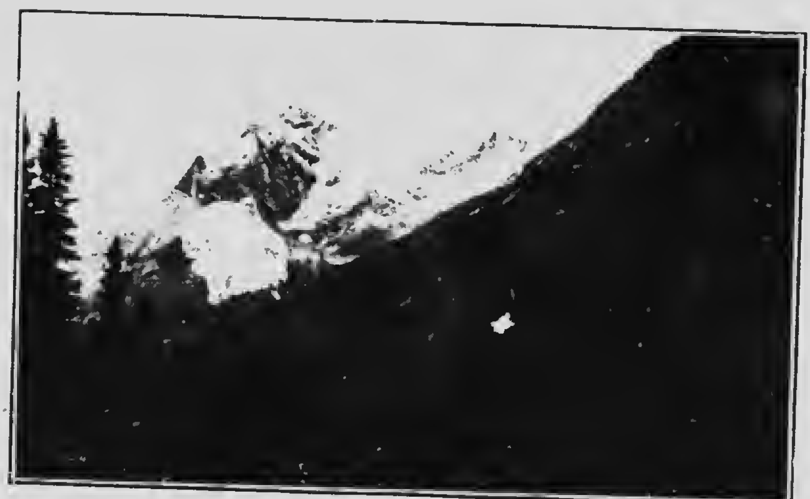
Fossil bed in "Burgess shale" on Mt. Field, showing character of the shale, method of quarrying for fossils, and temporary camp of C. D. Walcott.

almost perpendicular escarpment along the east side of Ottertail range where its cliff-forming character distinguishes it sharply from the adjacent shales. This limestone represents the uppermost member of the Cambrian in this part of the Rockies.

The whole Cambrian strata have been severely disturbed in periods of mountain building which succeeded their deposition. They now dip at many places at fairly high angles and have been compressed, sheared, and faulted. The folds, into which they have been bent, trend in the same direction as the mountain axes, a direction which is also followed by the faults. It is interesting to note that many of the valleys are located along lines of faulting, while others have been cut down into and along the crests of the folds.

ORDOVICIAN.

Ordovician strata succeed the Cambrian in regular order without any apparent break, and wherever the Ordovician beds have not been eroded away the conformable nature



Cambrian-Ordovician contact in Mt. Goodsir. The gray rock is the Ottertail limestone, overlain by the dark-colored Goodsir shales.

of their contact with the Cambrian is clearly shown. This contact can be best seen in Mt. Goodsir in the Ottertail range.

The Ordovician is exposed on the railway line between Leanchoil and Glenogle and again in the Columbia valley from Golden to Beavermouth. It has a total thickness of 7,740 feet and has been divided for convenience in description into the Goodsir shales and the Graptolite shales. The Goodsir shales include a lower part consisting of limy, siliceous, and clay shales which weather gray, buff, and yellowish, and an upper part consisting of banded cherts, cherty limestones and dolomites. The Graptolite shales consist of black, carbonaceous, and brown shales at the top, and gray shales at the bottom. They occur in two infolded bands in the Beaverfoot range and are well exposed in a creek a few yards west of Glenogle station.

The Ordovician is very rich in fossils, especially the Graptolite shales. The long stem-like graptolites with their single or double row of cells on either side are so abundant in the Ordovician as to give the period the name of "the Age of Graptolites."

The character of the Ordovician rocks shows that the great Interior sea in which these and the preceding formations were laid down was shallower than in the closing stages of the Cambrian though there is evidence to show that it had also widened. It is highly probable that the western half of the Canadian Cordillera was at this time still a land area, the erosion of which furnished the material for these sediments.

SILURIAN.

The Silurian is represented in the railway section only by a narrow band of quartzite and limestone immediately west of Glenogle where it is seen to rest conformably on the Ordocivian shales. No Silurian is known to be exposed in any other part of the railway belt. It has a total thickness near Glenogle of 1,850 feet, but as the upper part has been eroded away it may have been originally somewhat thicker.

The local name for the Silurian rocks in this section is Halsyite beds, so named on account of the fossil corals of that name which they contain. They contain also remains of crinoids, brachiopods and gastropods.

The absence of the Silurian in the eastern part of the Rockies suggests that this region was a land area during that period, and indeed this is quite likely for throughout

North America generally the Silurian was a period when the whole continent was elevated somewhat above the level that it previously had.

The Silurian is the youngest rock formation exposed in the western part of the Rockies.

DEVONIAN.

The Devonian includes probably the Sawback formation and certainly the Intermediate limestone and the greater part of the Lower Banff limestone, formations which occur about Banff in approximately parallel bands coinciding in strike with the trend of the axis of the mountains. The strata are frequently tightly folded and have been much disturbed and faulted. They consist mainly of limestones which were laid down in the Interior sea which at this time covered a great part of the interior of the continent.

The Intermediate limestone consists of thin-bedded limestones with harder layers of siliceous limestones. The rocks contain a high percentage of sulphur which has been derived from the decomposition of the iron pyrites in it. A strong odor of sulphuretted hydrogen is given off it when struck with a hammer. The hot springs at Banff are in this limestone and the sulphur in the water is probably derived from this source.

The Sawback formation lies conformably below the Intermediate limestone and consists of massive and thin-bedded limestone and shale. The age of this formation is still in doubt. It resembles some of the Silurian beds of the Beaverfoot range and may be of the same age.

The Lower Banff limestone overlies the Intermediate limestone, into which it grades so gradually that it is not always possible to draw a sharp line between them. It forms the eastern cliffs of Cascade Mountain and Mt. Rundle, and the steeper slopes of Sulphur Mountain.

The Devonian is called the "Age of Fishes" on account of the unusually large development of these animals which during the Ordovician and Silurian only began to make their appearance in obscure forms. No fossil fishes have yet been found in the Devonian of this part of the Rocky mountains though it is known to contain corals, brachiopods and bryozoans.

CARBONIFEROUS.

The name Carboniferous was given in the early history of geology when it was supposed that this period was everywhere characterized by the presence of coal seams. We now know that this idea is wrong, and although the Carboniferous does contain a large share of the world supply of coal, the formations of that period in the Caanadian Cordillera are all marine deposits and without coal.

It is customary to divide the Carboniferous into two distinct portions, the Lower, or Mississippian, and the Upper, or Pennsylvanian.

The Mississippian rests conformably on the Devonian but, in the section through which the Canadian Pacific railway runs, is not exposed except on the eastern part of the Rocky mountains. It includes the Upper part of the Lower Banff limestone and the Lower Banff shale. The Lower Banff shale is about 1,200 feet thick and consists of black and gray shales which weather brown.

The Pennsylvanian is also exposed in the eastern part of the Rockies as two formations, namely, the Upper Banff limestone and the Rocky Mountain quartzite, with a total thickness of 3,000 feet. The Rocky Mountain quartzite represents a shallowing of the Interior sea which 'iowever was not so muddy as to deposit shales.

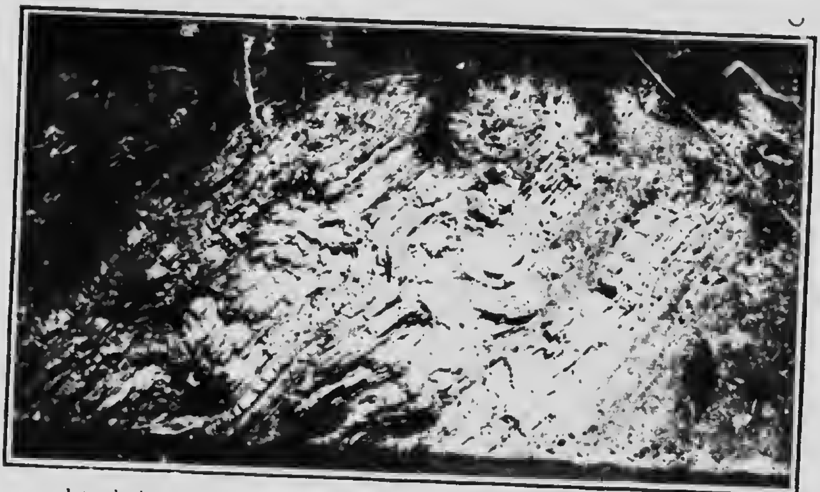
Rocks of Pennsylvanian age are extensively developed in the western part of British Columbia where they have been called by Dawson the Cache Creek group. They include, besides a great thickness of true sediment, many interbedded flows of volcanic rocks. They show that the western part of British Columbia, which had remained a land area since the earliest times, became in this period depressed beneath the sea and these rocks were laid down in that sea.

In structure the Carboniferous rocks of the Rocky Mountains are very much disturbed and the strata, besides being folded, have been broken, faulted, and overturned on each other. The result is that they now stand in highly inclined or vertical attitudes.

Fossil shells are abundantly preserved in the Carboniferous of this region.

Permian.

The Permian occurs only in the eastern part of the Rocky mountains where it is represented by the Upper Banff shale. This is a series of sandy shales and thin sandstone beds which occur as a narrow band crossing the Bow valley at Banff. It has a total thickness of 1,400 feet and rests conformably on the Rocky Mountain quartzite. The shales are soft and weather out easily, consequently the stream valleys are often located along their outcrops.



A typical view of the Upper Banff shale, exposed in Spray valley at Banff.

Like the Carboniferous the Permian rocks have been very much disturbed in the course of mountain building periods which followed their deposition, so that they have become folded and dip at high angles.

The Permian in North America was a period of general elevation of the land, while in South America and in other parts of the world the climate was so cold as to bring on a period of glaciation.

Triassic.

Triassic rocks are not definitely known to occur on the line of railway either in the Rockies or the Selkirks. They are however known to be present in the Rockies both to the north and to the south, but at some distance.

In the Interior Plateau region a thick series of Triassic rocks has been named by Dawson the Nicola group. These rocks are mainly volcanic flows associated with which are thin beds of limestone, an association which suggests that the volcanic flows were submarine in origin.

Other Triassic rocks occur in the western part of the Cascade range.

JURASSIC.

In the western part of the Cordillera the only Jurassic rocks are those of the upper part of the Nicola group. The only other Jurassic formation is the Fernie shale exposed in the Rocky mountains on the northeastern side of Bow river, and near Exshaw.

The Fernie shale formation consists of black and dark brown, thinly laminated shales which break into small angular fragments. It passes downwards into the Upper Banff shale and like the Upper Banff shale its strata are inclined at high angles.

The Jurassic was a period of great disturbance particularly in the western part of the Cordillera where the rocks were intensely folded and thrust up into mountain ranges. This disturbance apparently was not so great in the eastern part of the Cordillera and the effect of the movement, which appears to have had its origin in the Pacific, is not so noticeable. This disturbance was accompanied in the western Cordillera by the intrusion of great bodies of igneous rocks.

Life in the Jurassic is recorded in a great variety of forms and among the vertebrates the reptiles reached so high a stage of development that this has been called the Age of Reptiles. A few remains of these have been found in the Fernie shale which also contains many ammonites.

CRETACEOUS.

Following the disturbances in the Jurassic period, deposits of Cretaceous age were laid down in areas of depression on the Pacific coast, in the Interior Plateau region, and on the eastern slope of the Rocky Mountains.

On the eastern slope of the Rockies the Cretaceous sea covered a large area and in portions of this period extended as far east as Manitoba. Rocks laid down in this sea are now exposed along the line of railway from Mitford to Kananaskis and again in the valley of Bow river about Bankhead. They consist of sandstones, shales, conglomerates, and coal seams, with a total thickness of over 11,000 feet. In the foothills region these rocks have been gently folded into a series of parallel ridges, but in the main ranges of the Rockies they have been much more severely disturbed and compressed so that the strata now stand at high angles. In places the folds have been completely overturned by thrust exerted from the west so that the Cretaceous rocks now lie underneath rocks of a much older period.

The important formation in the Cretaceous of this region is the Kootenay which at Bankhead contains 14 seams of coal and at Canmore almost twice as many. The coal is bituminous and anthracitic.

The remains of both animal and plant life are abundant in the Cretaceous. The common plants are ferns, cycads and conifers. These have accumulated to such an extent in certain horizons as to form the coal seams. The animal remains of the Cretaceous include the dinosaurs and other reptilian monsters of the foothills region.

TERTIARY.

The elevation of the Rocky Mountains is believed to have taken place during the Cretaceous. This was a long and slow movement which appears to have forced the shore of the Interior sea gradually eastward, reducing its area, until at the beginning of Tertiary times it was a fresh water basin which lay some distance east of the main ranges of the Rockies. In this basin the yellowish sandstones and bluish gray shales of the Paskapoo formation were laid down. These cover the region east of Cochrane, and have been very little disturbed from the position in which they were first laid down.

In the western part of the Cordillera the Tertiary formations include both sedimentary and volcanic rocks. The sedimentary rocks were laid down in small isolated lake basins and consist of sandstones, shales and coal seams. They contain many plant remains and some fossil fish. The volcanic rocks are very widespread and of great thickness. They are mainly surface flows, though there are also some volcanic ash beds, which originated from a number of centres throughout the Interior Plateau region. The volcanic eruptions which produced these rocks extended throughout a great part of Tertiary times and continued with interruptions almost down to the present. Mt. Baker, which lies just to the south of the International Boundary line and is visible from Vancouver has only recently become extinct.

QUATERNARY.

The Tertiary rocks are the youngest consolidated rocks in this portion of the Canadian Cordillera. The later geological formations are loose or only partially consolidated deposits of Glacial and post-Glacial age which are scattered everywhere over the surface of the older rock formations.

GEOLOGICAL HISTORY.

The geological formations briefly described in the preceding pages contain the evidence from which the events in the history of the Cordillera can be worked out. These events include, the laying down of the rocks in the form of sediments in the ancient seas, the retreat of the waters and the emergence of the land above them, the erosion of the land by the action of the asmosphere and water, the elevation, folding, and crumpling of the rocks to form mountain ranges, the uprising of molten igneous rocks through the overlying sedimentary strata into the upper parts of the earth's crust, the action of volcanic forces, the development and progress of plant and animal life, and a number of other incidents of greater or less importance.

The earliest record of events that can be read in the rocks of the Cordillera carries us far back in the history of the earth to a time possibly preceding the advent of any life. This record tells us of the laying down of the rocks of the Shuswap series in an ancient and now dried up sea whose limits cannot now be definitely defined but which certainly covered the central part of Southern British Columbia. The formation of these rocks in the sea presupposes the existence of a land area somewhere in the neighbourhood the erosion of which furnished the materials for the Shuswap sediments. The position, extent and origin of that land area are unknown, and its history is hidden in the obscurity of the distant past.

After the deposition of the Shuswap sediments in that sea volcanic eruptions broke forth and lavas (Adams Lake greenstones) welling up through fissures in the earth's crust poured out over the Shuswap sediments and buried them deeply. The weight of these lavas in the long course of succeeding time metamorphosed the underlying sediments and converted them into laminated rocks known as schists and phyllites or into the hardened clay rocks metargillites.

Igneous rocks in a molten state also made their way upward into them from the heated interior of the earth, and, ramifying all through them in successive stages, altered them in places almost beyond recognition.

This complex mass of igneous and sedimentary rocks was then raised above the sea and became a land area, whose surface extended over the western half of the Cordillera. This region then persisted as a land area from that time through the succeeding periods of the Beltian, Cambrian, Ordovician, Silurian, Devonian and into the middle of the Carboniferous. As a land area it became subject to the eroding influence of the atmosphere and running water and was worn down, the materials worn off it being carried eastward by streams and deposited in an interior sea basin which covered the present site of the Selkirks and the Rockies. The floor of this basin slowly subsided by the weight of sediments deposited on it and, more or less continuously from Beltian to the middle of the Carboniferous, the sediments laid down in it increased in thickness forming the strata of which the mountains were afterwards built. At times the shores of this basin fluctuated responding to movements in the earth's crust but water remained in it as a sea almost continuously.

At the beginning of Upper Carboniferous or Pennsylvanian times the land area on the west began to subside and the sea advanced over it so that the whole of southern British Columbia became submerged with the possible exception of a few islands of Shuswap rocks in the central part and some volcanoes in the western. In this sea, limestones, formed by the accumulation of shells of marine animals, were deposited along with material derived by erosion from adjacent lands, and flows and ash beds from the volcanoes.

The Permian was a period of general elevation of the continents, and throughout this and the Triassic period the sea withdrew from a great part of southern British Columbia except the eastern part of the Rockies and parts of the Interior Plateau region. Much of the western part was never again covered by the sea.

The Jurassic is remarkable for the profound disturbance that took place at that time in the rocks of the earth's crust along the whole Pacific coast of North America. This disturbance was not pronounced in the Rocky Mountain portion of British Columbia where comparative peace reigned, and the normal conditions of sedimentation prevailed in a sea which covered that part of the continent. This sea widened in Cretaceous times and extended far eastward over the region of the Great Plains accumulating on its floor a great thickness of sandstones and shales. Coal seams were also laid down at times by the accumulation of thick beds of vegetable material where the region became wholly or partly drained.

With the completion of the thick beds of sediments that had been accumulating in the Rocky Mountain region through long ages the conditions were ripe for mountain building. At the close of the Cretaceous revolutionary disturbances began and the mountains began to be raised up. As in preceding revolutions the pressure was directed from the Pacific and for the first time since the Pre-Cambrian its effect was felt in the extreme eastern portion of the Cordillera. Here the strata were arched upward, compressed, and overturned on each other, and up-folded portions were pushed miles to the eastward over the level plains region. The shortening of the Cordilleran region by folding and compression must have reduced its width by many miles, and McConnell has estimated that the eastern part of the Rocky mountains alone was reduced from a width of 50 miles to one of 25 miles.

By the dawn of Tertiary times the Cordillera was developed in full vigour of mountainous relief and its subsequent history was in general one of erosion, that is to say, the carving out of its valleys by the streams and the development of its drainage systems and a general wearing down of its mountain ranges. Some sedimentary rocks were however laid down during Tertiary times namely on the eastern side of the mountains, and in isolated lake basins in the Interior Plateau region. Volcanic action was also prevalent in the western part of the Cordillera during much of this time

The Glacial period then followed during which the topography of the Cordillera was greatly changed and deposits of glacial origin such as gravels, clays, and loose unconsolidated materials were spread out over the surface of the older rocks by the glaciers themselves or by streams flowing out from the glaciers. Subsequent changes in the region are relatively slight and with the exception of the forest growth, the landscape is much the same as it was left on the disappearance of the ice sheet.

MINERAL RESOURCES.

With the exception of coal the mineral deposits of the region between Calgary and Revelstoke are not of very great importance. They include coal, brick clays, cement materials, marble, ornamental and building stone, lead and zinc and certain other deposits of less importance.

Mining is being carried on for coal on a seam in the Belly River formation of the Cretaceous which outcrops at Radnor. The important coal bearing rocks however belong to the Kootenay formation, and a number of seams belonging to this formation are being mined at Canmore and at Bankhead.

Cement is manufactured at Exshaw, the limestone for which is obtained at Exshaw while the shale is quarried from Laggan.

The beautiful blue mineral sodalite occurs on the border of an eruptive body of nepheline syenite in Ice River valley southwest of Field. The pure mineral makes a handsome ornamental stone when polished, and it may be obtained in sufficient quantity to make it commercially important. The syenite itself is sufficiently free from fracturing as to make it a good building stone.

Building stone is also quarried from the sandstone of the Paskapoo formation at Calgary.

Crystalline limestone or marble occurs in the Yoho valley at a point two miles from the mouth of the Yoho river.

Clays from which brick of different kinds could be manufactured occur at Golden, Field and in Yoho valley.

Native quicksilver has been found in the gravel of Kicking Horse river at Field, and cinnabar, the sulphide of mercury, is reported to occur in the limestone on the north side of the valley between Emerald and Amiskwi, but neither of these occurrences have proven to be important.

The most important metalliferous deposit in this part of the Rockies is the Monarch mine at Field. The mine is situated on the face of Mt. Stephen about 1000 feet above the railway. The ore consists of silver-bearing galena and zinc blende occurring in veins which traverse limestone. The mine was first opened in 1885 but has never been a large or regular producer.

ANNOTATED GUIDE.

CALGARY TO REVELSTOKE.

Miles.	Altitude.	
0·	3,425 ft.	**Calgary**—This is the most important city on the main line of the Canadian Pacific Railway between Winnipeg and Vancouver. It is beautifully situated at the junction of the Bow and Elbow rivers near the western edge of the Great Plains and within sight of the snowy peaks of the Rocky mountains. The bed rock formation underneath the surface covering of unconsolidated glacial material is a soft sandstone belonging to the Paskapoo formation. This rock is quarried in the vicinity and makes an excellent building stone.
9·4	3,551 ft.	**Keith**—Beyond Calgary the railway
22·8	3,748 ft.	**Cochrane**—follows the valley of Bow river passing in a few miles from the rolling prairie country to the more hilly region of the foothills. Bow river here cuts its valley into the sandstones of the Paskapoo series, a formation which extends as far west as Cochrane. At Cochrane the beds of this series dip eastward forming the western limb of a great shallow syncline or downwarped basin of these rocks.

Miles.	Altitude.	
		Beyond Cochrane the disturbance which resulted in the elevation of the Rocky mountains becomes evident in the rocks as well as in the general topography. East of this the rocks are comparatively undisturbed and were beyond the zone of influence of the mountain building forces that caused the crumpling and folding of the strata in the mountains. West of Cochrane however the strata become more and more distorted and irregular in their attitude, and from here through to the Pacific coast there are evidences on every hand of gigantic earth movements and mighty volcanic forces uniting to produce a variety of scenery that is unrivalled anywhere in the world.
34	3,865 ft.	**Radnor**—The coal-bearing rocks that
42	4,066 ft.	**Morley**—underlie the Paskapoo formation are brought to surface beyond Cochrane, and at Radnor a coal seam in the Belly River formation is being mined. Beyond Radnor to Kananaskis the railway crosses the belt of foothills and the disturbed condition of the rocks is apparent in the outcrops that may be seen from the railway. These rocks consist of sandstones, shales and some conglomerate belonging to various divisions of the Cretaceous. At Horseshoe falls and Kananaskis falls the Bow river plunges over beds of conglomerate which are so hard that the river has not been able to cut into them as it has in the softer rocks associated with the conglomerates. Kananaskis falls are situated just below the mouth of Kananaskis river and while they are not visible from the railway the roar that they make is easily heard.
54	4,218 ft.	**Kananaskis**—The railway enters the Rocky mountains proper a few miles beyond Kananaskis and the boundary between the foothills and the mountains

Miles. Altitude.

is marked by the steep wall-like front of the mountains which rise abruptly from the foothills. This steep face is characteristic of the eastern border of the Rockies and is a feature that has been developed as a result of the mode of origin of the mountains. We have already seen how the Rockies were elevated by an enormous compressive force directed from the Pacific side, and as a result of this pressure the originally horizontal strata were arched upward into folds, the folds compressed, and finally broken into blocks and thrust one over the other towards the east. The steep eastern face of the Rockies is the eastern edge of these great overthrust blocks. Another result of the overthrusting of the strata is that the sequence of the rocks is here inverted and we find that the old Cambrian rocks which originally lay farther west have been pushed eastward over younger Cretaceous rocks and now rest directly on top of them.

At Kananaskis the railway enters the Rocky Mountains Park and continues in it up to Stephen.

57 4,247 ft. **Exshaw**—The cement manufacturing
63 4,236 ft. **The Gap**—plant at Exshaw is one of the largest in Canada. The limestone for the cement is quarried from the mountain side, but the shale is obtained from near Laggan.

Between Kananaskis and The Gap the Bow river cuts a narrow gorge-like valley directly across the trend of the ranges. The mountains rise steeply on either side and are composed of beds of limestone which dip at high angles towards the west. The rocks in this gap are heavily grooved and striated by the great glacier which at one time flowed down it into the foothills region. These grooves and

Miles.	Altitude.	
		striations were formed by rock fragments carried along on the bottom of the glacier.
67	4,283 ft.	**Canmore**—Beyond the Gap, Bow river occupies a wide longitudinal valley which has been excavated by the stream along the strike of a belt of soft Cretaceous rocks. The valley is generally floored with shingly terraces and contains a number of open patches of prairie. Canmore is situated on one of these prairies which was [illegible]merly known by the Stoney Indians [illegible] "[illegible]he prairie where they shot the little [illegible]." The underlying rocks of the va[illegible] floor are sandstones and shales of [illegible]retaceous age, while the slopes on either side are mainly of older limestones of Devonian and Carboniferous ages. The sandstones and shales are associated with coal seams and together they constitute a coal basin of considerable importance that has become isolated by erosion from the main Cretaceous areas to the east of the mountains. The coals in these basins in the mountains are of higher grade and their value has been enhanced by the pressure to which they have been subjected in the course of mountain building. Other isolated coal basins of similar value occur in the eastern ranges of the Rockies both to the north and the south of the main line of the Canadian Pacific. The coal is bituminous and several seams are being mined on the slope of the mountain opposite Canmore.
		Immediately behind Canmore and all along the side of the valley above are groups of peculiar pillars known as hoodoos. These are remnants of glacial material that have resisted the erosive action of rain and wind often by the aid of a boulder which now caps the hoodoo.

Miles Altitude.

79·5 4,510 ft. **Bankhead**—The wide valley which the railway enters at The Gap is known as the Cascade trough and up this the railway continues as far as Bankhead where are other coal mines worked by the Canadian Pacific Railway Company. The coal seams here dip south-westward into the base of Cascade Mountain and are mined by a cross-cut tunnel which intersects several coal seams. The coal is bituminous and is associated with sandstones and some shale. The coal bearing formation continues up the valley of Cascade river but the railway here turns sharply to the southwest and passing between Cascade Mountain on the north and Tunnel Mountain on the south reaches the Bow river again at Banff. The course of the railway between Bankhead and Banff lies in an abandoned channel of Bow river continuous with that in which Lake Minnewanka lies, but this channel, having become obstructed by the gravels brought down by Forty Mile creek and by a large glacial moraine, the river was forced to turn southward and flow around the south side of Tunnel Mountain.

Cascade Mountain overlooks Bankhead from the northwest and the structure of the rocks in it is well shown and typical of the general structure of the eastern ranges of the Rockies. The beds dip sharply to the west and terminate in a steep cliff on the east. At the base of the mountain is the cliff-forming Intermediate limestone (Devonian), over laid by the Lower Banff limestone (Lower Carboniferous). Higher up is the easily weathering Lower Banff shale (Lower Carboniferous) and on the top of the mountain are the Upper Banff limestone and the Rocky Mountain quartzite (Upper Carboniferous). All of these

Miles.	Altitude.	
		formations have been thrust over from the west on the top of the younger coal-bearing Cretaceous rocks which occupy the floor of the valley. The plane of separation between these old rocks and the Cretaceous is a fault line which continues down the southwest side of Bow valley past Rundle mountain, the Three Sisters, and on in the same direction across the Crowsnest pass and into Montana where it is known as "Lewis thrust." On the plane of this fault line and along others lying east and west of it McConnell has calculated that the front ranges of the Rocky Mountains have been pushed seven miles to the east from their original position.
82	4,521 ft.	**Banff**—The town of the Banff is the centre and distributing point for the whole Rocky Mountains Park and is beautifully situated on Bow river near the mouth of the Spray. To the north are Cascade mountain and a smaller ridge, Stoney Squaw mountain, in which is shown the eroded end of an irregular fold in the strata. Looking west up Bow valley the snow-capped peaks of the Bourgeau range are visible 10 miles away. On the southwest and southeast are Sulphur and Rundle mountains with Spray river flowing down between them. The valley of Spray river is floored with shales of Permian and Jurassic age which are softer than the adjacent rocks and are consequently more easily weathered out to form a valley. The valley is also a line of dislocation or faulting in the strata whereby the same beds that occur in Sulphur mountain are repeated in Rundle mountain. The Fernie shales of this locality are characterized in certain layers by an abundance of fossil ammonites.

The hot springs are situated on the east slope of Sulphur mountain. The upper spring is 500 feet above the town and gives a water that is high in sulphur and has a temperature of 114·2 degrees Fahrenheit. A second hot spring is 200 feet lower down the slope and a mile and a half farther northwest. This spring is not as strong as the upper and the temperature of its water is about 90 degrees. A third spring situated about 50 feet above Bow river contains water of a lower temperature than the other two. This spring is locally known as the "Cave and Basin" because it rises in a cavern 20 feet in diameter and after flowing through an underground channel escapes to a natural basin built up of the calcareous material that it carries in solution. These and other springs rising in the bottom of Bow valley near Vermilion lakes are all in the Intermediate limestone (Devonian). The waters probably obtain their sulphur content from the decomposition of the iron pyrites in the limestone.

The structure of these ranges of the Rocky mountains can be clearly seen from the summit of Sulphur mountain. They show how the strata have been broken into long blocks along lines which are now marked by the longitudinal valleys, and how the eastern sides of these blocks have been tilted up and perhaps pushed over the adjacent block to the east. The result is that the same beds of one range are repeated in the range adjacent to it.

Leaving Banff the railway follows the broad swampy valley of Bow river with the stream on the lefthand side and Vermilion lakes on the other. The valley is here a transverse valley cutting directly across the axes of the ranges. The rocks on either side are westerly-

Miles.	Altitude.	
		dipping Carboniferous, Permian and Jurassic strata. Healy creek on the south side of the railway is the route to Mount Assiniboine, the Matterhorn of the Canadian Rockies. It is also the route to Simpson Pass, a pass by which Sir George Simpson crossed the mountains in 1841 during his journey around the world.
88	4,537 ft.	**Sawback**—The railway turns sharply to the northwest at Sawback and from that point to Laggan, Bow river flows in a broad longitudinal valley that lies parallel to the strike of the rock formation. On the northeast is the Sawback range built largely out of limestones, and terminating at the south in Mt. Hole-in the-wall. This mountain is so called because of the great cave in its side 1,500 feet above the valley. The cave has probably been formed by water running through it and making a passage that is 150 feet long and about 50 feet in diameter at its mouth. The formation here is the Lower Banff limestone (Carboniferous).
93·	4,600 ft.	**Massive**—On the southwest side of Bow valley at this point. Pilot mountain rises to a height of 9 680 feet above the sea, its base consisting of Devonian limestone and its peak of Upper Carboniferous. A few yards beyond the west end of the siding the railway cuts through some dark brown Fernie shales which contain a number of fossil ammonites. This block of shales is entirely out of place and has been dropped down by faulting to it. present position between older rocks.
99·	4,660 ft.	**Castle**—As the railway enters farther and farther into the heart of the mountains it passes through strata that are

Miles.	Altitude.	
		successively older than the preceding ones to the east until at Castle we come to the oldest formation (Pre-Cambrian) that is found in the Rockies. This is because the uplift has been greater in the interior than in the outer ranges and the action of denudation has consequently been greater. The result is that the younger rocks which at one time perhaps formed the uppermost beds of the interior ranges have been worn away and the old rocks towards the base of the sedimentary series have become exposed at the surface. From Castle to Laggan, Bow river flows in what is known as an anticlinal valley, that is to say, the valley has been cut down into and along the crest of a fold or anticline in the strata. The bottom and lower slopes of the valley are composed mainly of Pre-Cambrian shales while the higher slopes are occupied by Cambrian limestones and shales. Castle was a town of about 1,500 inhabitants during a mining boom in 1884-86 when deposits of copper were found in Copper mountain on the opposite slope of the valley. Opposite Castle is the entrance to Vermilion pass through which an automobile road is being built to the valley of Columbia river.
105·5	4,817 ft.	**Eldon**.—From Castle the railway follows the base of Castle mountain for 10 miles. This mountain is in appearance one of the most remarkable in Bow valley. The eastern end terminates in a pinnacle which from the railway resembles a ruined castle and gives the name to the mountain. The top of the mountain is capped by Upper Cambrian limestones and shales of the Bosworth formation. The perpendicular cliffs at the top are of the Eldon formation. Below this the Stephen formation forms an easy talus-

covered slope, while the precipitous slope below this again is of the Cathedral formation. These three formations are Middle Cambrian in age. The brush covered irregular slopes at the base are of Lower Cambrian quartzites. Between Eldon and Laggan the mountains on the southwest side of Bow valley are bold and impressive and include some of the highest peaks in this part of the Rockies. Mt. Temple (11,620 ft.), the highest in the

Castle Mountain, showing Cathedral limestone in the lower cliffs; Stephen formation in the talus covered slope; and the Eldon formation in the upper cliffs.

range, is built of Lower Cambrian quartzites and shales. The valleys cutting into this range, namely the Valley of the Ten Peaks, Paradise, and Lake Louise valley all head in glaciers and are typical hanging glacial valleys. They are called hanging valleys because there is an abrupt steepening of the grade of the valleys as they enter the valley of the Bow river, a steepening which in certain instances is so great as to produce direct falls in the streams flowing down them, The hanging valley effect is believed to have been produced by excessive deepening of the main valley over that of the side valley by the glacier which once flowed down it.

Mt. Temple, showing a complete Lower and Middle Cambrian section capped by Upper Cambrian, and underlain by Pre-Cambrian shales (covered by talus).

Miles.	Altitude.	
115	5,037 ft.	**Laggan**—A carriage drive and railway lead from Laggan westward to Lake Louise and the Lakes in the Clouds. Lake Louise is 2½ miles from Laggan and 600 feet above Bow river, and is situated at the outer end of a great glacial cirque which is occupied at the other end by Victoria and Lefroy glaciers. Lake Agnes and Mirrow lake lying north-west of Lake Louise also occupy glac . cirques. They are rock basins goug . out by the action of a mountain gla . r which once lay on the site of the lakes. Lake Louise is surrounded by Lower Cambrian quartzites, of which the St. Piran formation stands out in precipitous cliffs. Middle Cambrian limestones overlie the quartzites and form the summits of t' e highest mountains such as Aberdeen, Lefroy and Whyte.

Miles.	Altitude.	
		Laggan is on Pre-Cambrian slates and shales, a good exposure of which may be seen 200 yards west of the station. One mile west of Laggan the railway leaves the Bow river and follows up the valley of Bath creek to the summit of Kicking Horse pass. Looking up Bow valley and to the right of it Mt. Hector (11,125 ft.) may be seen with its castellated cliffs of Lower and Middle Cambrian formations. Six miles beyond Laggan and within a mile of Stephen is a quarry in the Pre-

The Mitre and Death Trap (pass) to the right. The cliffs on the right are of Middle Cambrian limestone in Mt. Lefroy. A typical bergschrund is shown around this portion of the Lefroy glacier.

		Cambrian from which shales are mined and transported to Exshaw for use in the manufacture of cement.
122·	5,329 ft.	**Stephen**—This is the station of the continental divide where the waters of a small stream coming down from the mountains to the south part into two branches, one to flow westward by way of the Columbia river to the Pacific and the other eventually reaching Hudson bay by way of the Bow, Saskatchewan and Nelson rivers. Kicking Horse pass

Miles. Altitude.

was discovered by Sir James Hector in 1876. It is a broad transverse valley about 2 miles wide carved out by a stream which probably once had its source farther to the west than the present divide. Kicking Horse river in consequence of its greater fall has cut back further eastward and captured the head waters of this stream. Kicking Horse pass, however, must have been widened by the action of a valley glaciers flowing ... ard to Bow valley, evidence of which ... seen in the striated rock ... gravel deposits on the summit imp... presence of a considerable body of water at levels higher than are now ... The rocks at the summit are of ... and Middle Cambrian age and ... on the north side ...

125· 5,207 ft. **Hector.** ... ent of Kicking Horse river, which ... the pass, is at first very rapid, and a steep sided canyon has been cut by the river through the Middle Cambrian and into the Lower Cambrian formations. Before entering the first of the two special tunnels an excellent view may be had of Yoho valley, a glacial U-shaped depression which heads in Yoho glacier. At Takakkaw falls, 1,248 feet in height, Yoho river cascades over Middle Cambrian limestone, and at Twin falls higher up the valley, the stream falls over the same formation.

The two spiral tunnels are respectively 3,200 and 2,900 feet in length and were constructed in order to reduce the grade of the railway from 4·4 per cent to 2·2 per cent. The upper one is cut into Lower Cambrian quartzites and the lower in Middle Cambrian limestone. Before entering the second spiral tunnel a good view is obtained of the broad

Miles Altitude

glacier-formed valley of the Kicking Horse river. Its bed is covered with gravelly bars evidencing the great volume of water which at certain seasons must descend from the mountains. On the south side of the valley are Cathedral mountain and Mt. Stephen picturesque spurs of the northern end of Bow range built out of Lower and Middle Cambrian beds with a great fault of 3,000 feet thrown between them.

The Monarch mine, situated on the precipitous slope of Mt. Stephen 1,000 feet above the railway, is a lead mine containing lead and zinc sulphides in fissures in the limestone. A concentrating mill, on the left of the railway, has recently been constructed to separate the sulphides from the gangue.

Passing through a short tunnel in St. Piran quartzite the railway hugs the base of Mt. Stephen gradually descending to the floor of the valley until at Field it is only 10 feet above the river.

0. 4,064 ft. **Field**—This is a divisional point where in going westward the time changes from Mountain to Pacific Time. It is also the distributing point for Yoho Park and the starting point for Emerald lake, Yoho valley and Ice river.

It is charmingly situated near the base of Mt. Stephen and facing Mts. Field and Burgess. On the slope of Mt. Stephen, 2,600 feet above the railway, and in a lentile of shale in the Stephen formation is the famous trilobite fossil bed from which 32 species of tribolites and brachiopods have been determined by Dr C. D. Walcott. Another fossil bed prolific in animal remains has recently been discovered in the west slope of Mt. Field. These beds contain the shell impressions of marine animals living in the ancient

Miles. Altitude.

sea that at one time covered the present site of the mountains. These animals dying, their shells were quickly covered with sediments, and impressions of them preserved, thus giving us an insight to the conditions of life at that time. These beds are of Middle Cambrian age.

Two miles west of Field the Kicking Horse river contracts to a narrow canyon and passes under a natural bridge formed of Upper Cambrian shales and slates.

3·5 3,895 ft. **Emerald**—From this point down to Leanchoil the valley of Kicking Horse river has been excavated in Upper Cambrian shales and limestone, the soft shales of the Chancellor formation forming easy talus-covered slopes and the limestone of the Ottertail formation steep cliffs.

Ottertail escarpment, showing Chancellor formation, forming talus-covered, undulating surface; Ottertail limestone in cliffs; and Goodsir shales on gradual slopes.

8 3,696 ft. **Ottertail**—The valley contracts below Ottertail and in the banks are good exposures of the purplish grey Chancellor slates and shales. Beyond Wapta the

Miles. Altitude.

railway turns at a sharp angle to the northwest and cuts off a sharp bend in the river. At this bend is Wapta falls where the river falls over steeply tilted slates. Beaverfoot river enters near this point through a wide valley by which in pre-Glacial times the Kicking Horse river joined the Kootenay river. Glacial moraines having collected in this valley the Kicking Horse river was diverted along its present course to the northwest.

17 3,681 ft. **Leanchoil**—Beyond the ridge southeast of Leanchoil, of which Chancellor peak (10,751 ft.) forms the culminating point, lies Ice River valley in which is exposed the only igneous rock in this section through the Rocky mountains. It is intrusive into the Upper Cambrian rocks and contains the rare blue mineral sodalite. This is one of the few places in which this mineral occurs in such quantity that it may be mined. Leanchoil is on the line of the great fault by which the Upper Cambrian beds of Mt. Hunter have been lifted up and now lie in contact with the shales of the Ordovician. The plane of this fault is shown in the steep face of Mt. Hunter.

23 3,283 ft. **Palliser**—Glacial gravels and clay
28 2,991 ft. **Glenogle**—have accumulated to a depth of 200 feet in the valley near Palliser, and some hoodoos may be seen in process of formation out of this material. West of Palliser the valley narrows and the railway plunges into the lower Kicking Horse canyon, a steep-walled gorge cut into highly inclined shales of Ordovician and Silurian age. Through this canyon the river forces a difficult and stormy passage and only emerges from it on reaching the broad Columbia valley at Golden. The

Miles.	Altitude.	
		structure of the rocks in the canyon is very complicated and numerous faults and overturned folds indicate the enormous compression and distortion to which the strata have been subjected in the process of mountain building. The Silurian limestones here are interesting as containing numerous slender fern-like fossils known as graptolites. A number of mineral springs rise out of this limestone and some of the water from them, on testing, has proved to be strongly radioactive.
35	2,578 ft.	**Golden**—At this point the railway enters the valley of Columbia river, a deep wide depression hundreds of miles in length known to geologists as the Rocky Mountain Trench. This trench separates the Rocky mountains from the Purcell mountains from Beavermouth southward, and from that point northward, it is the boundary between the Rocky mountains and the Selkirks. It is a feature old as the Rocky mountains themselves and its origin is believed to be connected primarily with the processes that produced those mountains. A great fault or line of dislocation in the bed-rock follows the western side of the valley north and south of Golden. This fault has caused the strata on the west side of the valley to be elevated several thousand feet relative to the beds in and on the east side of the valley. The faulting may in itself have caused the valley by the down sinking of a longitudinal block of strata, but it certainly weakened the rocks along the line of the valley and rendered them less resistant to the action of erosion so that streams flowing in the valley easily cut their way down into the bed rock. The excavation of the valley was done in stages, each successive stage in deepening

Miles. Altitude.

following an uplift of the region. By these uplifts the grade of the stream was increased and with increase of grade came the power to deepen its valley. Faulting therefore appears to have been the primary cause in the location of the valley; and its development has been completed by stream erosion.

42 2,548 ft. **Moberly**—Loose deposits of glacial and stream deposition are so widespread in the Columbia valley between Golden and Donald that rock exposures are very rare. The rocks constituting the Purcell mountains on the southwest side of the valley are all siliceous sediments of Beltian age. On the northwest side of the valley are Silurian and Ordovician shales and limestones very much crumpled and disturbed. The strata both of the Purcell and Selkirk mountains are never as folded or broken as those of the Rockies. This might appear strange when we consider that they must have been subjected to the same compression and mountain building forces which caused the folding and elevation of the Rocky Mountain strata, but since they are older, more massive and rigid than the Rocky Mountain strata, they never yielded to the same extent, and instead of close folds, and overthrust folds they lie in broad open folds and have comparatively few faults.

52 2,574 ft. **Donald**—About a mile beyond Donald the railway enters a long series of rock cuts where the river leaves the main Rocky Mountain trench and cuts a long canyon through folded and mashed Paleozoic shales and limestones. The diversion of the stream has probably been caused by glacial blocking of the main valley and has separated a block of

Miles. Altitude.

mountains from its main structural equivalent, the Dogtooth mountains. About a mile east of Beavermouth the railway crosses the great Trench fault where the crumpled Paleozoic shales and limestones cease and are succeded by the less deformed Beltia [illegible] zites, slates and schists.

63· 2,430 ft. **Beavermouth** [illegible] situated on the Columbia [illegible] th of the Beaver river [illegible], which the railway turns [illegible] cross the Selkirk mountains. [illegible] y of Beaver river is part of the Purcell trench, a topographic feature similar to, but of less magnitude than, the Rocky Mountain trench, separating the Purcell mountains from the Selkirks. The trench is continuous from this point southward into the United States at Bonner's Ferry a distance of over 200 miles. Here, in its northern part, the trench is a valley of erosion excavated by the stream in the rocks along the crest of a broad fold. The trench has been deepened and widened by a valley glacier, causing the development of hanging valleys on the streams flowing into it. The railway crosses several of these. On the southwest side of the valley are many glacial cirques several of them being still occupied by mountain glaciers. The rocks of the trench are quartzites of the Cougar formation dipping on either side under the Nakimu limestone and Ross quartzite. About seven miles beyond Beavermouth the railway enters the limits of Glacier National Park which extends westward to Illecillewaet.

78· 3,663 ft. **Bear Creek**—Near the junction of Bear creek and Beaver river is the entrance to a double track railway tunnel

Miles. Altitude

which will cross the main divide of the Selkirks emerging at the loop beyond Glacier. The length of the tunnel will be 4·6 miles. Beyond Bear Creek station the railway turns up Bear Creek crossing from the Cougar quartzite over the Nakimu limestone into the Ross quartzite. The beds here dip towards the west and form the eastern limb of a broad downfold or syncline the western limb of

Looking south from Mt. Tupper to Mt. MacDonald and Mt. Sir Donald (background) showing part of the summit syncline of the Selkirks as shown in the Sir Donald quartzite forming the great escarpment. Photograph by Howard Palmer.

which is on the western side of Rogers pass. This syncline, as shown in the geological structure section, forms the main divide of the Selkirk mountains and its middle part is occupied by the Sir Donald quartzite. The Sir Donald quartzite is the rock constituting the highest portion of the mountain peaks in this part of the mountains.

Miles.	Altitude.	
84.	4,302 ft.	**Rogers Pass** This station is situated on the axis of the main Selkirk syncline and the flat lying beds of the axis can be seen on the mountain slopes to the north. Northwest from here the railway folllows the axis of the syncline over the summit of the pass to Glacier.
87.	4,086 ft.	**Glacier** This is the centre of the Glacier National Park and the point from which trails radiate to all the most interesting points in the Selkirk mountains. Here one may study the phenomena of living glaciers to better advantage than from any other point on the Canadian Pacific Railway. Illecillewaet glacier, which drains a snowfield about 10 square miles in area, can be reached in 30 minutes' walk over a good trail. The Asulkar glacier is also within easy reach. All the glaciers are gradually dwindling and their retreat is easily noticeable from year to year, indicating that the loss to the glaciers by melting is greater than the gain by precipitation.

The summit ranges of the Selkirks are built mainly out of quartzites of the Sir Donald formation. This is a Lower Cambrian formation and is the youngest formation found in this section of the Selkirks. They correspond in age with the rocks about the summit of the Rocky mountains, but have not yet been found to contain fossils. Though very old they are not so old that life did not exist on the earth at the time of their formation, so that a careful search may yet prove the presence of animal remains in them. The structure of the Selkirks is simple compared to the Rockies, as a glance at the structure section will prove. The dips of the strata on the west side are in general towards the east so that in proceeding westward along the railway line we

Mt. Tupper from Rogers Pass. Slopes underlain by Sir Donald quartzite.

Miles. Altitude.

pass in regular sequence over older and older rocks until at Albert Canyon we come on to the oldest rocks of the whole Canadian Cordillera.

Leaving Glacier the train begins a rapid descent down the valley of Illecillewaet river making a loop at Loop brook. Cougar watertank is at the mouth of Cougar brook up which a trail runs to the caves of Nakimu (Caves of Cheops).

Mt. Sir Donald from Eagle mountain; Mt. Uto in foreground. Photograph by Howard Palmer.

These are irregular tunnels in the Nakimu limestone dissolved out by the water and occupied by Cougar brook for a part of its course.

95· 3,435 ft. **Ross Peak**—At this point the gray and rusty Cougar qu. rtzite which is exposed in Beaver river on the east side of the Selkirk range comes to the surface

Miles. Altitude.

again. It is here more massive and homogeneous than where first seen at the mouth of Beaver river.

103· 2,707 ft. **Illecillewaet**—Two miles beyond Ross Peak station the railway passes over from the Cougar quartzite into older rocks of the Albert Canyon division which as far as Albert Canyon consist of dark grey to black, metamorphosed argillites. These are hardened clay rocks which are either massive or fissile according to the alteration that they have undergone.

109· 2,221 ft. **Albert Canyon**—The gorge at Albert Canyon is a narrow cut made by Illecillewaet river in the argillites. They are here associated with some thin lenses of limestone and are cut by a small igneous dyke. Between the gorge and the station are a few rock-cuts in quartzite and argillite. At Albert Canyon an interesting contact may be seen on the bank of Albert creek between the gneiss of the Shuswap series and the sedimentary rocks of the Albert Canyon division. The contact is not sharp but is believed by Daley to be an unconformable one, that is to say, a long interval of time is believed to have elapsed between the formation of the Shuswap gneiss and the deposition of the Albert Canyon rocks on top of it. During this interval the gneiss was exposed and was subject to the action of erosion and the material eroded off its surface went to form the sediments of the Albert Canyon division. All these rocks were afterwards covered up by a great thickness of overlying rocks and the dead weight of these overlying rocks altered them to their present condition. Denudation, continued throughout a very long period of time, has again brought these rocks to the surface.

Orthogneiss near Albert Canyon station, schistosity due to static metamorphism.

Miles	Altitude.	
119.	1,872 ft.	**Twin Butte**
124.	1,667 ft.	**Greely**

From Albert Canyon to Revelstoke the railway passes across a section of the Shuswap series composed mainly of gneisses and schists. The gneisses are altered granites which were injected in the form of dykes, sheets, and irregular bodies into the schists. The schists are perhaps sediments which have been changed to their present condition by the intrusion of the granite and by pressure. The whole series is believed to correspond in age with the Laurentian and other pre-Cambrian rocks in Eastern Canada because, like them, they contain no evidence of life.

The region covered by the Shuswap series represents the most ancient land area that we know of in Western Canada. Its rocks constitute part of the oldest rock series of the earth's crust and from the erosion and denudation of this area much of the sedimentary series of rocks that form the Selkirks and Rockkies was made up. The complex character of these rocks is shown only at a few points in Illecillewaet valley. Four miles beyond Greely the river cascades over schists and gneisses and at this point the power plant for the town of Revelstoke has been built. Turning sharply to the right the railway passes through delta deposits of sand and gravel that were deposited by the Illecillewaet river in the Columbia valley at a time when the valley was occupied by a lake. The level of these deposits is about 230 feet above that of the Columbia river showing that the level of the lake was about that height. It is probable that the lake in which they were deposited was an expansion of the present Arrow lake.

Miles.	Altitude.	
150.	1,492 ft.	**Revelstoke**—The town lies in Columbia River valley which here bounds the Selkirk mountains on the west and separates it from the Columbia Mountain system, formerly known as the Gold ranges. The origin of the valley is not definitely known, but it has probably been formed by erosion along a line of faulting and dislocation in the rocks. From the point the railway leaves the Columbia river at Beavermouth the stream flows around the northern end of the Selkirk mountains and at Revelstoke runs southward into the Arrow lakes.

Geological Survey, Canada

Route ma

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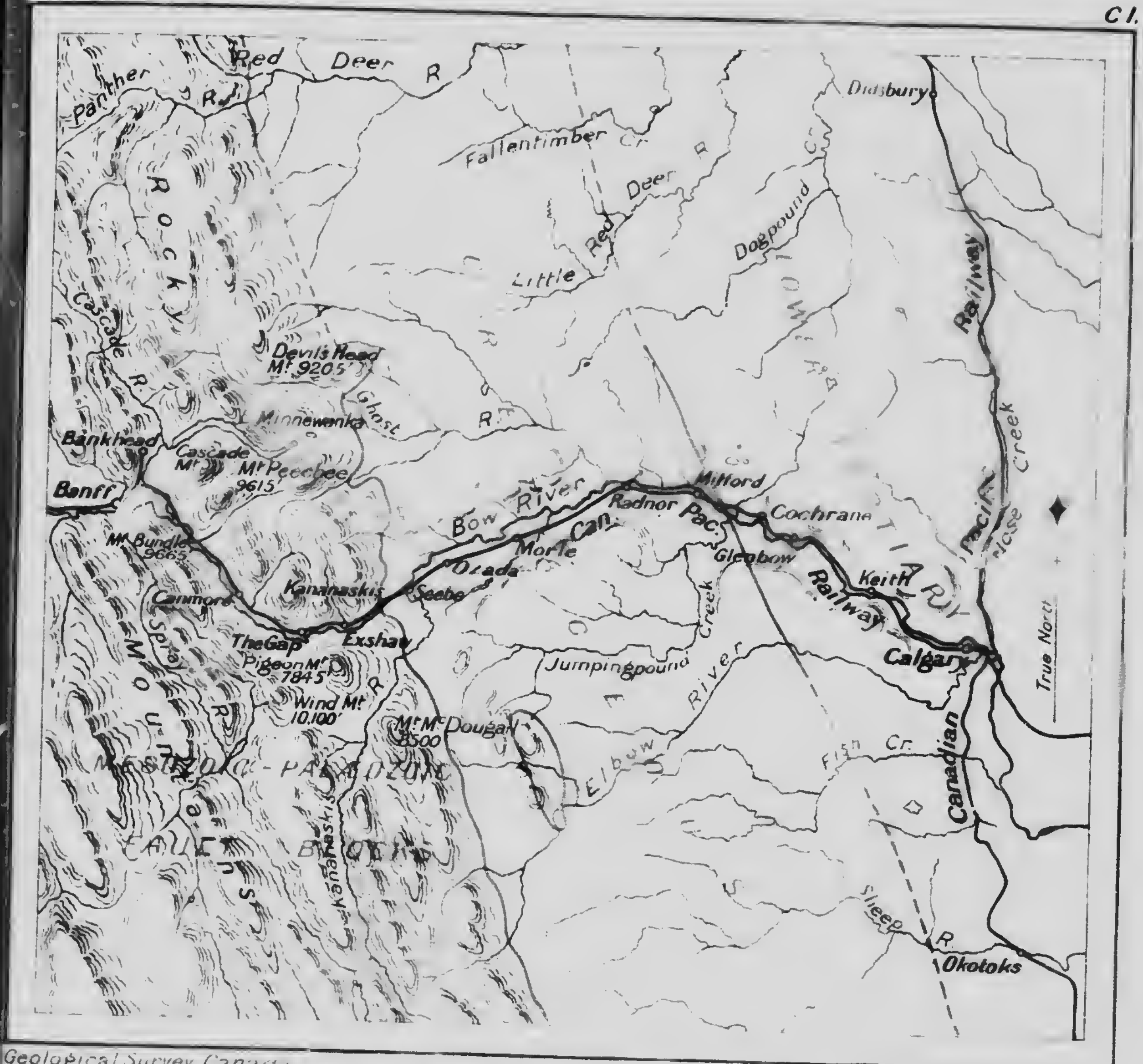
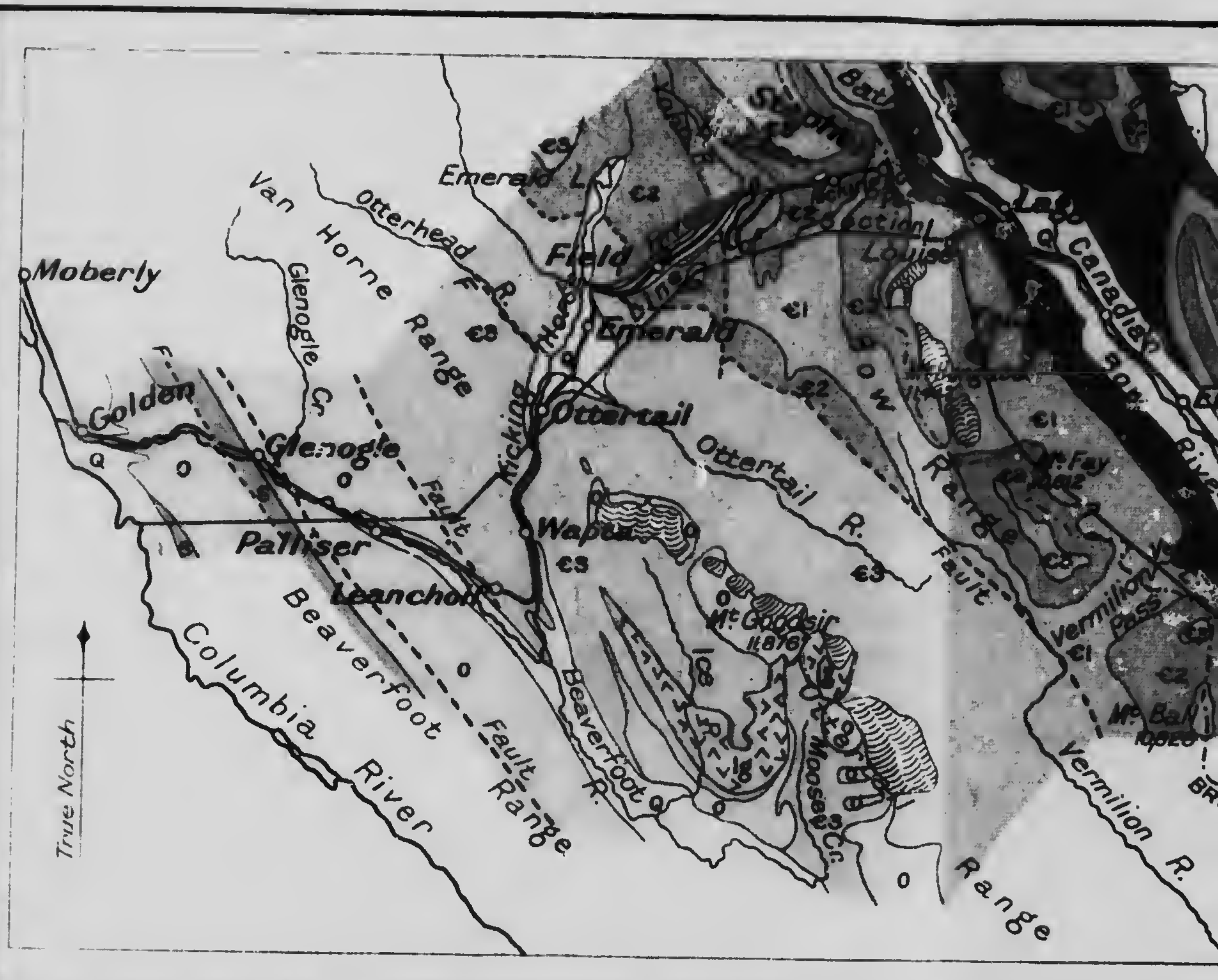


Geological Survey, Canada

Route map between Calgary and Banff

Miles: 5 0 10 20 30 40

Kilometres: 5 0 10 20 30 40 50 60



ological Survey, Canada.

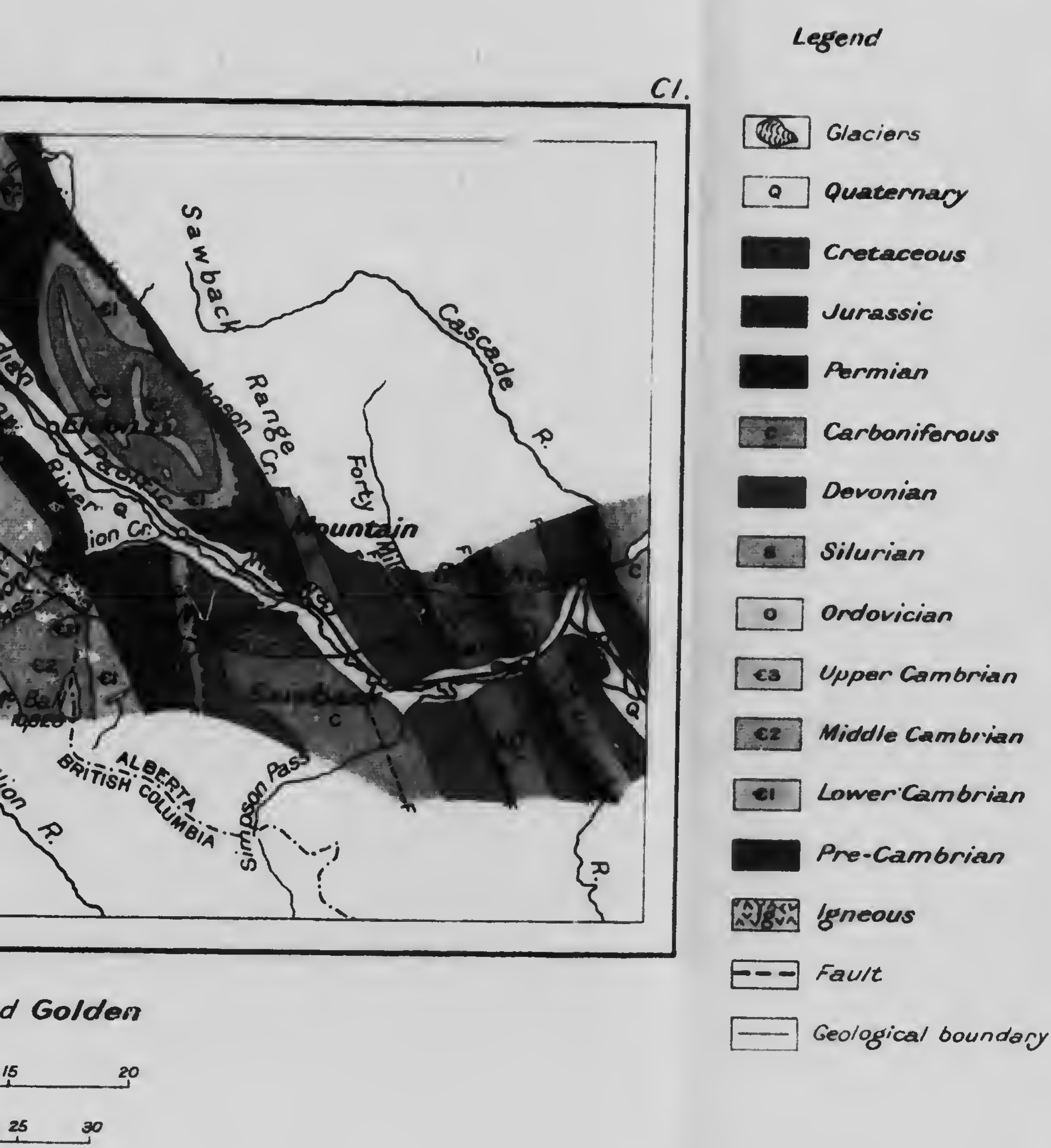
Route map between ***Banff and Gol***

Miles

5 4 3 2 1 0 5 10 15

Kilometres

5 0 5 10 15 20 25

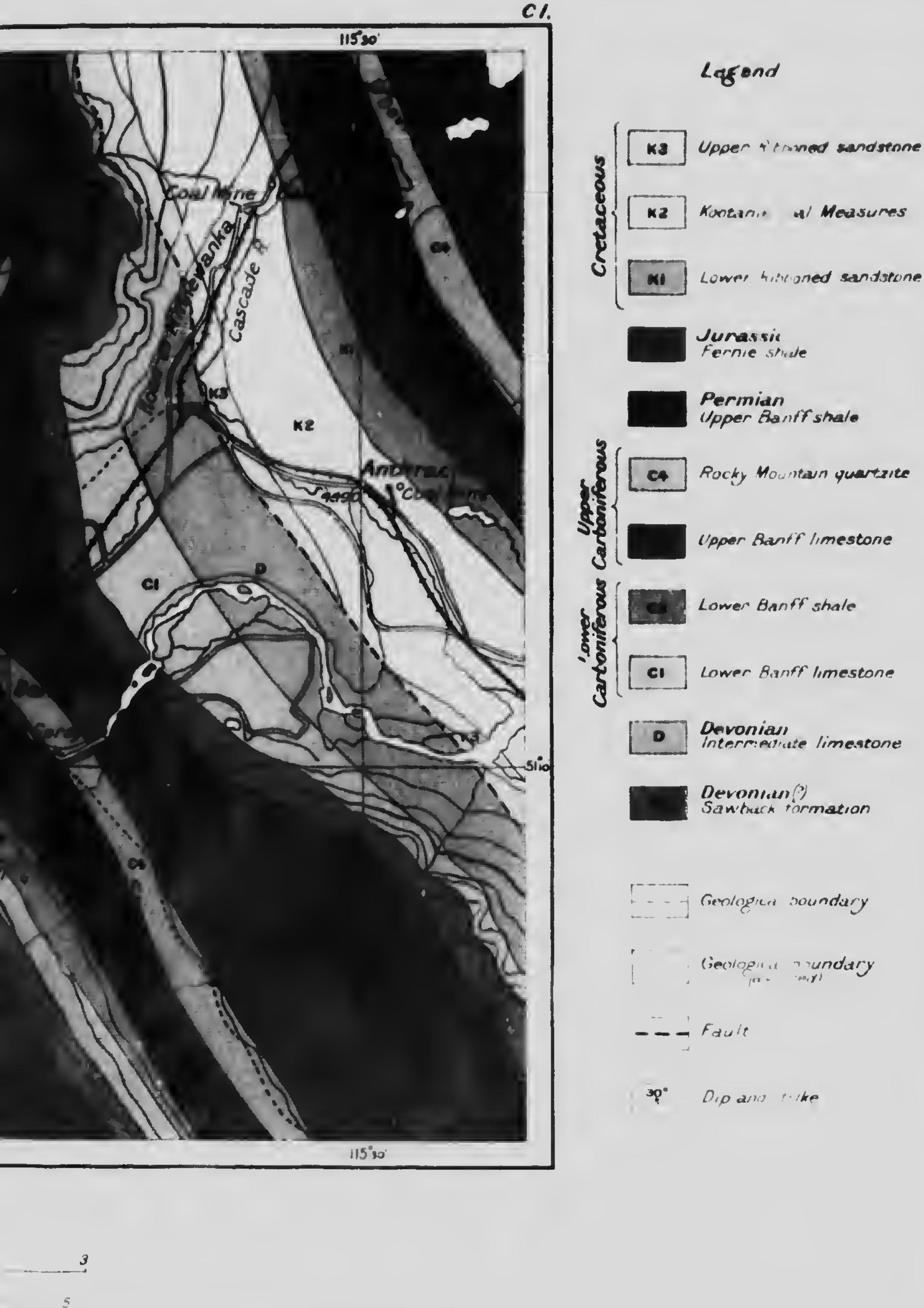

Legend
Glaciers
Quaternary
Cretaceous
Jurassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Upper Cambrian
Middle Cambrian
Lower Cambrian
Pre-Cambrian
Igneous
Fault
Geological boundary
C1.
Sawback
Cascade R.
Range
Forty
Mountain
River
Pacific
ALBERTA
BRITISH COLUMBIA
Simpson Pass
Simpson
R.
d Golden
15
20
25
30

Geological Survey, Canada

Banff

Miles

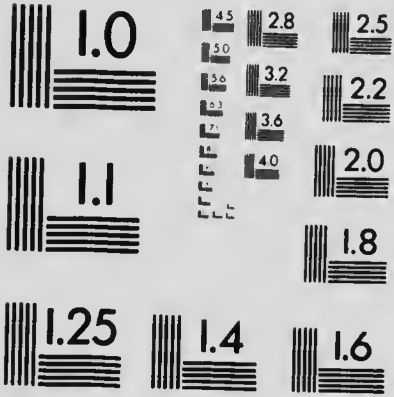
Kilometres



Cl.
115°30'
Coal Mine
Minnewanka
Cascade R.
K1
K2
K3
C4
C1
D
Anthrac
Coal
4490
51°10'
115°30'
Legend
Cretaceous
K3 Upper Ribboned sandstone
K2 Kootanie Coal Measures
K1 Lower Ribboned sandstone
Jurassic
Fernie shale
Permian
Upper Banff shale
Upper Carboniferous
C4 Rocky Mountain quartzite
Upper Banff limestone
Lower Carboniferous
Lower Banff shale
C1 Lower Banff limestone
Devonian
Intermediate limestone
Devonian(?)
Sawback formation
Geological boundary
Geological boundary
Fault
30° Dip and strike
3
5

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Geological Survey, Canada

Laggan – Field

Miles

Kilometres

CI.

Legend

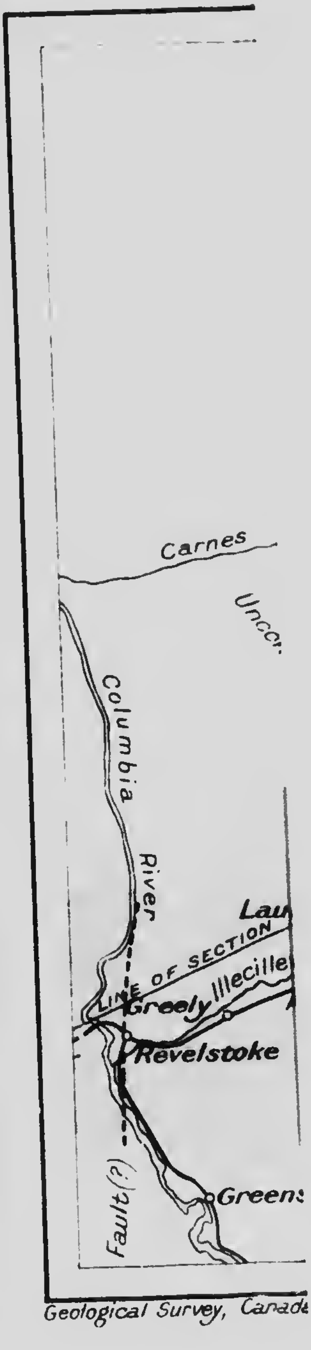
Upper Cambrian: €5	Ottertail limestone
Upper Cambrian: €4	Chancellor shale
Upper Cambrian: €3	Sherbrooke, Paget, and Bosworth formations
€2	**Middle Cambrian** Eldon, Stephen, and Cathedral formations
€1	**Lower Cambrian** Mt Whyte, St Piran, Lake Louise, and Fairview formations
(black)	**Pre-Cambrian** Hector and Corral formations

Geological boundary

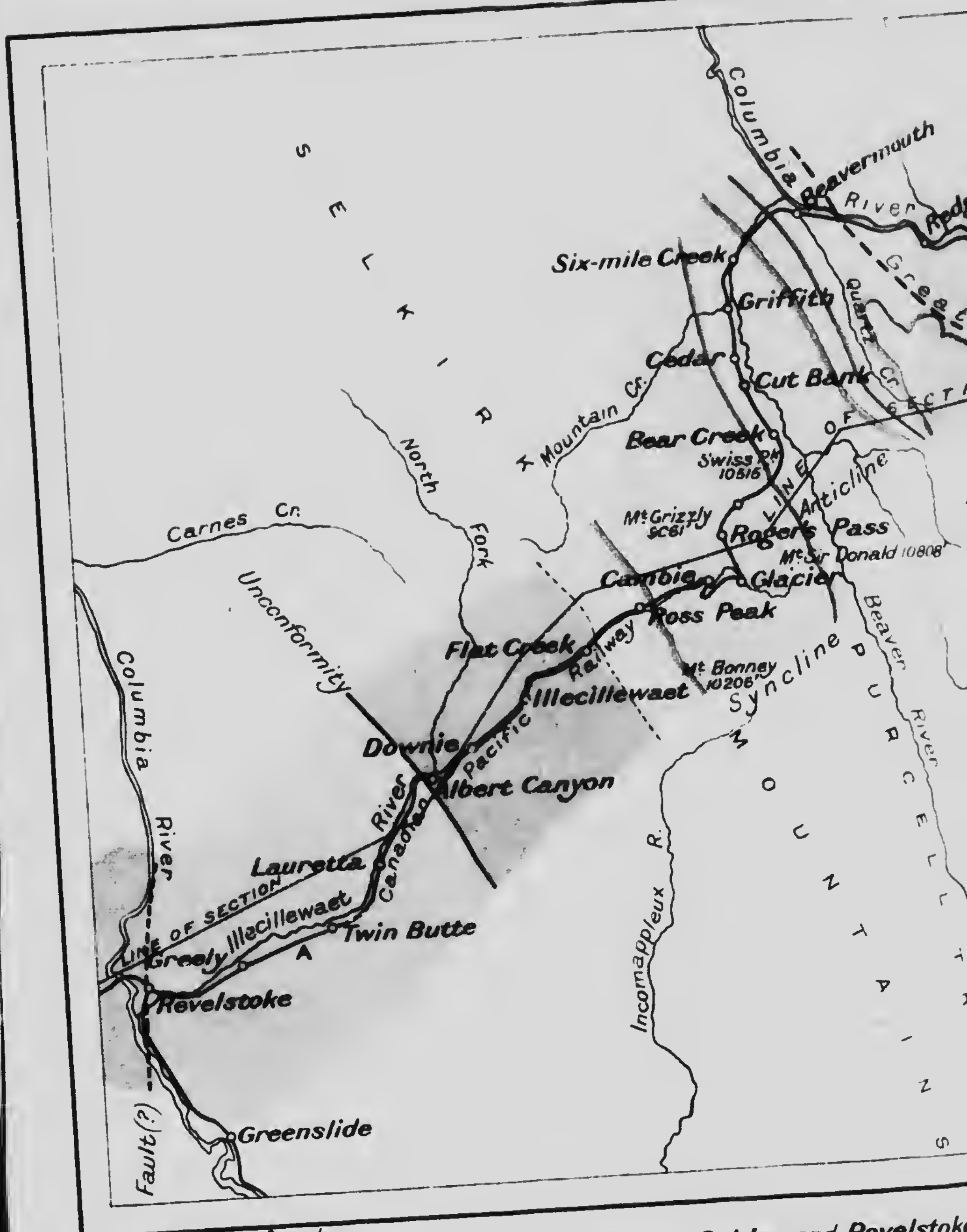
Geological boundary (assumed)

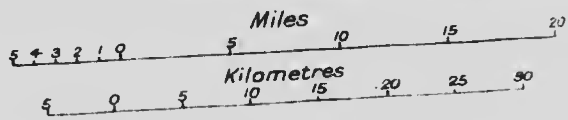
Fault

Continental divide



Geological Survey, Canad





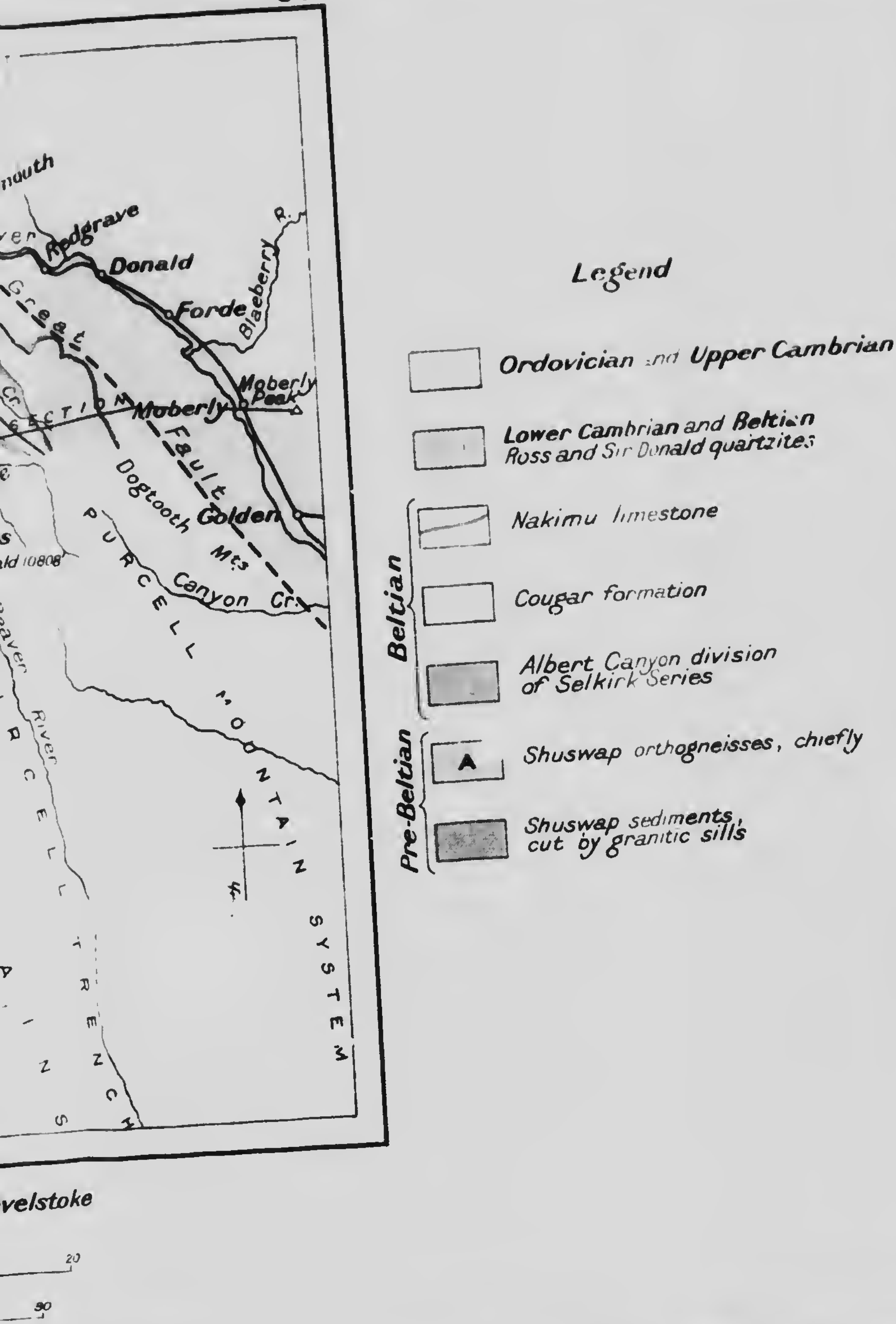
Geological Survey, Canada.

Route map between **Golden** and **Revelstoke**

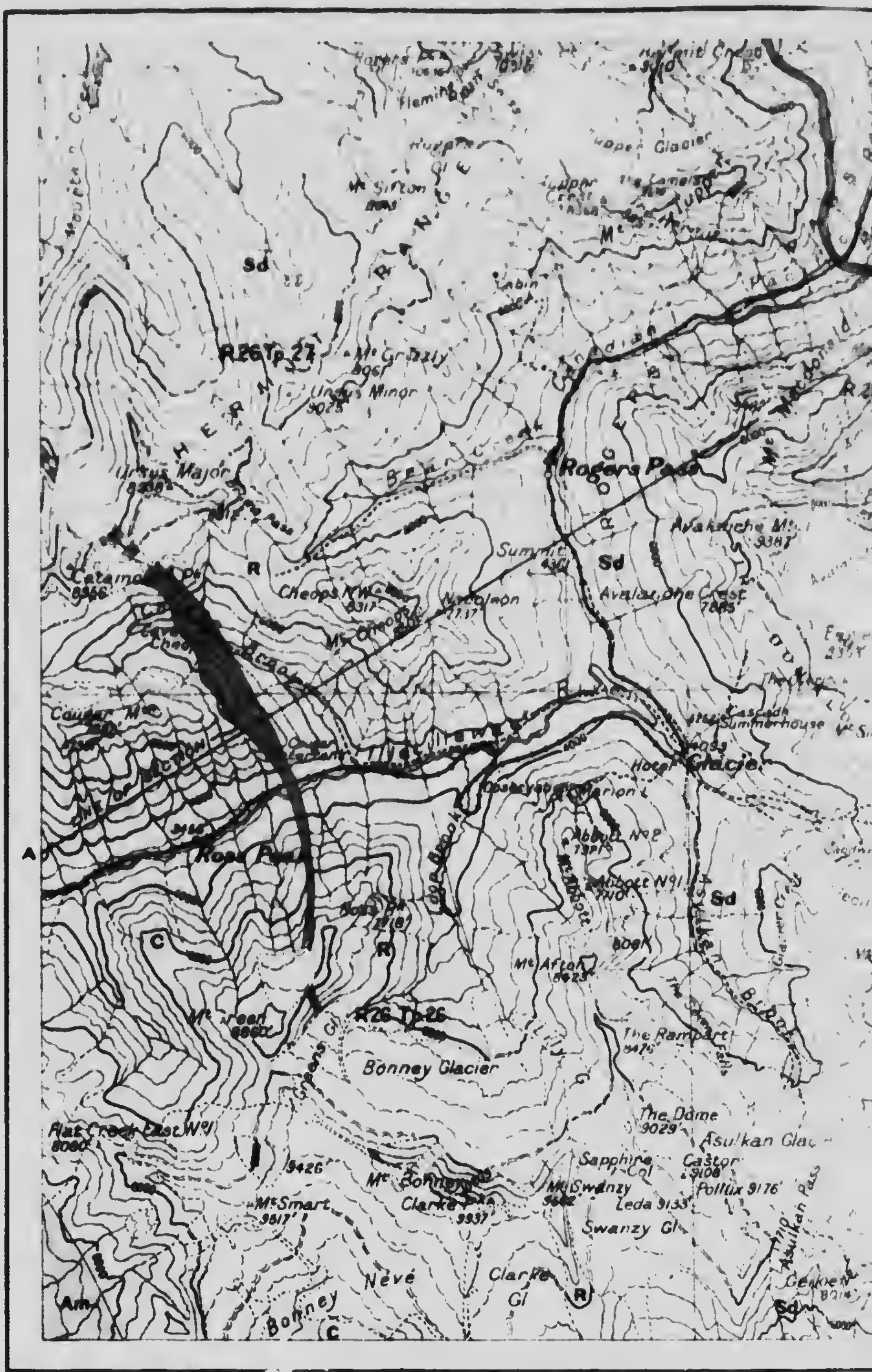
Miles

Kilometres

Cl.



mouth
Redgrave
Donald
Forde
Blaeberry R.
Great
Fault
Moberly
Moberly Peak
Dogtooth Mts
Golden
Canyon Cr.
PURCELL
MOUNTAIN SYSTEM
River
PURCELL TRENCH
ald 10808
velstoke
20
30
Legend
Ordovician and Upper Cambrian
Lower Cambrian and Beltian
Ross and Sir Donald quartzites
Beltian
Nakimu limestone
Cougar formation
Albert Canyon division of Selkirk Series
Pre-Beltian
A
Shuswap orthogneisses, chiefly
Shuswap sediments, cut by granitic sills

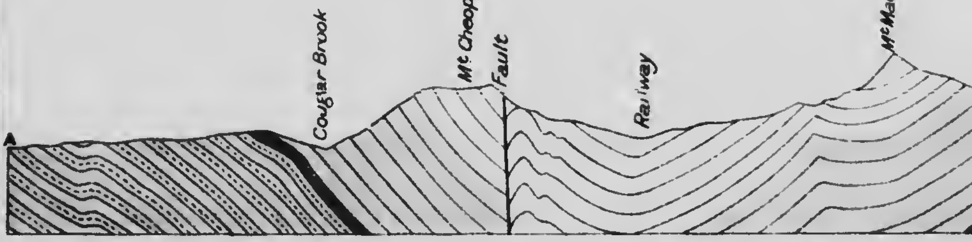


Geological Survey, Canad

Glacier

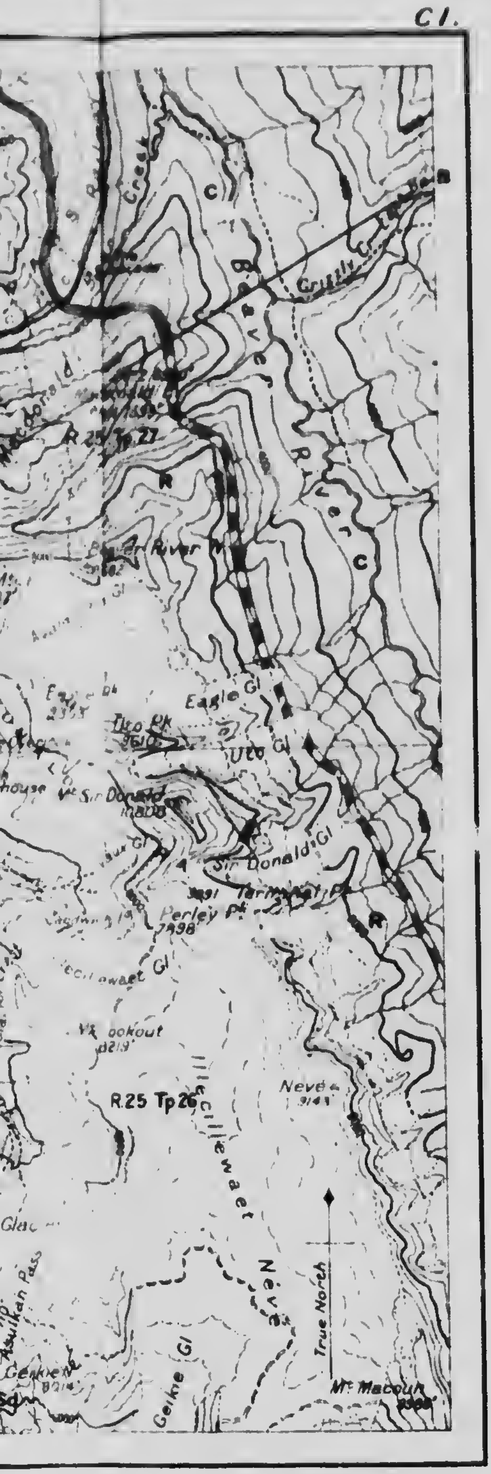
Miles

Kilometres



Section along line AB

CI.



Legend

Glacier and snow-field

Sd Sir Donald quartzite

R Ross quartzite

Nakimu limestone

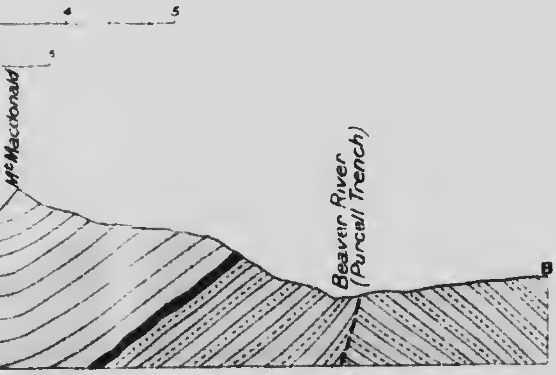
Nakimu limestone (mapped approximately)

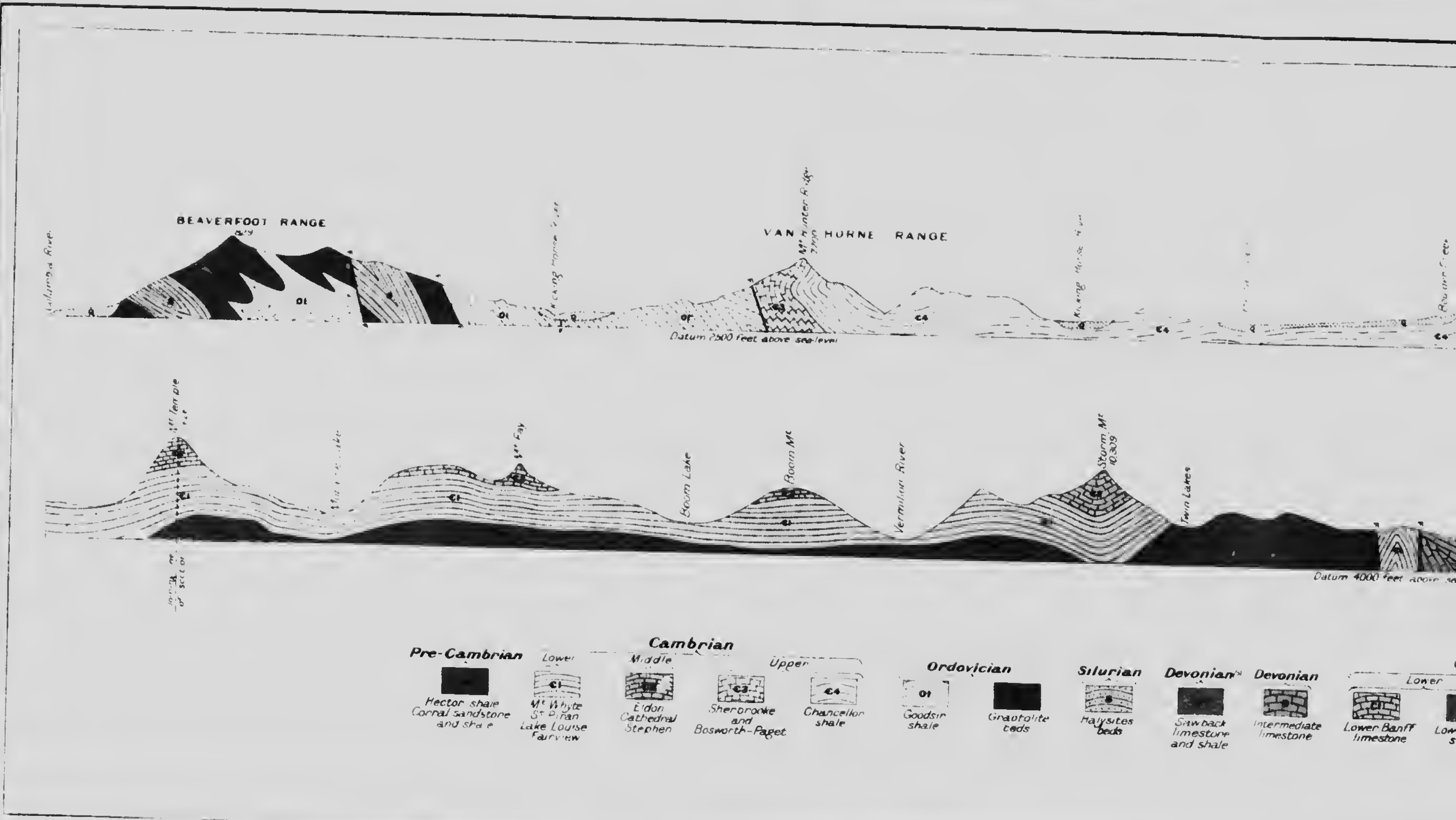
C Cougar formation (quartzite, metargillite)

Beltian

Am Phyllitic metargillite youngest member of Albert Canyon division of Selkirk series

Note—Faults not shown on the map



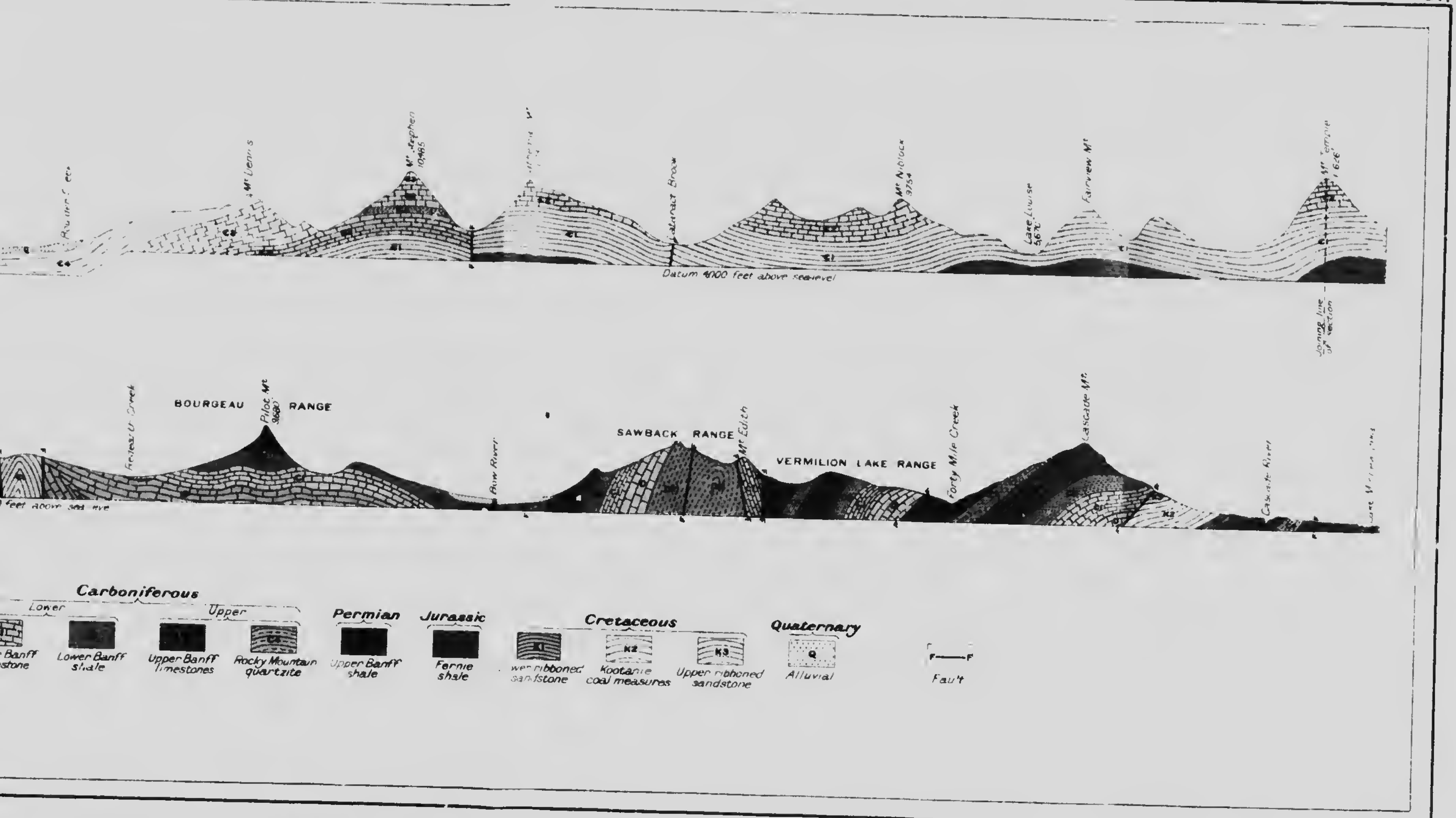


Geological Survey, Canada

***Structure Section** across the **Rocky Mountains** near the*
*between the **Cascade Trough** and*

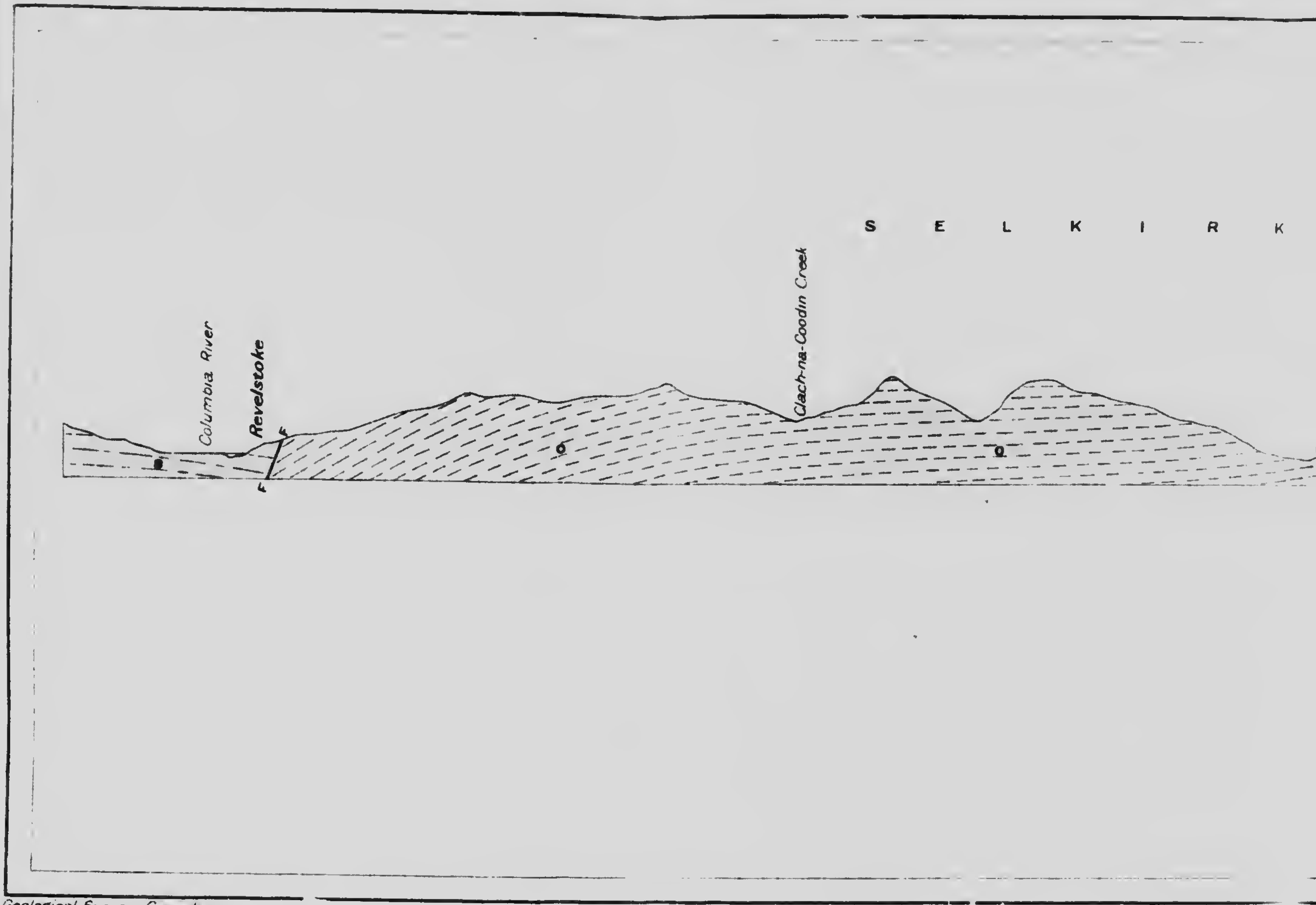
Horizontal and Vertical
Miles
Kilometres

Cl.



near the **Main Line** of the **Canadian Pacific Railway**
ough and the **Columbia Valley**

d Vertical scale
Miles
ilometres



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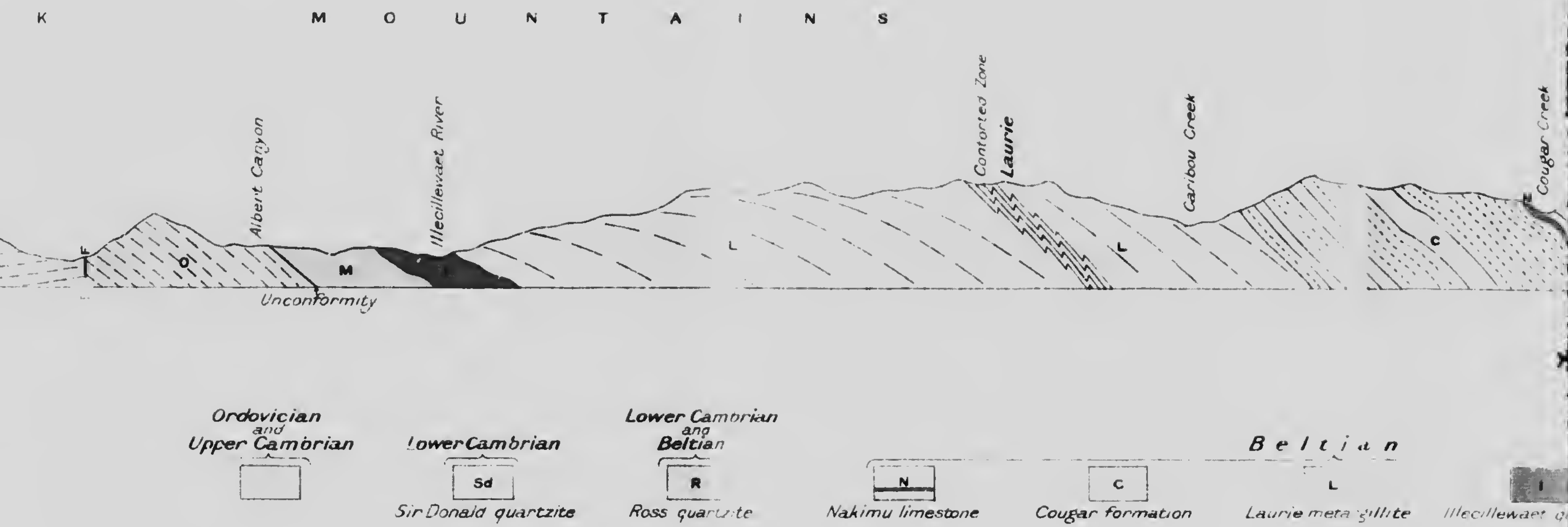
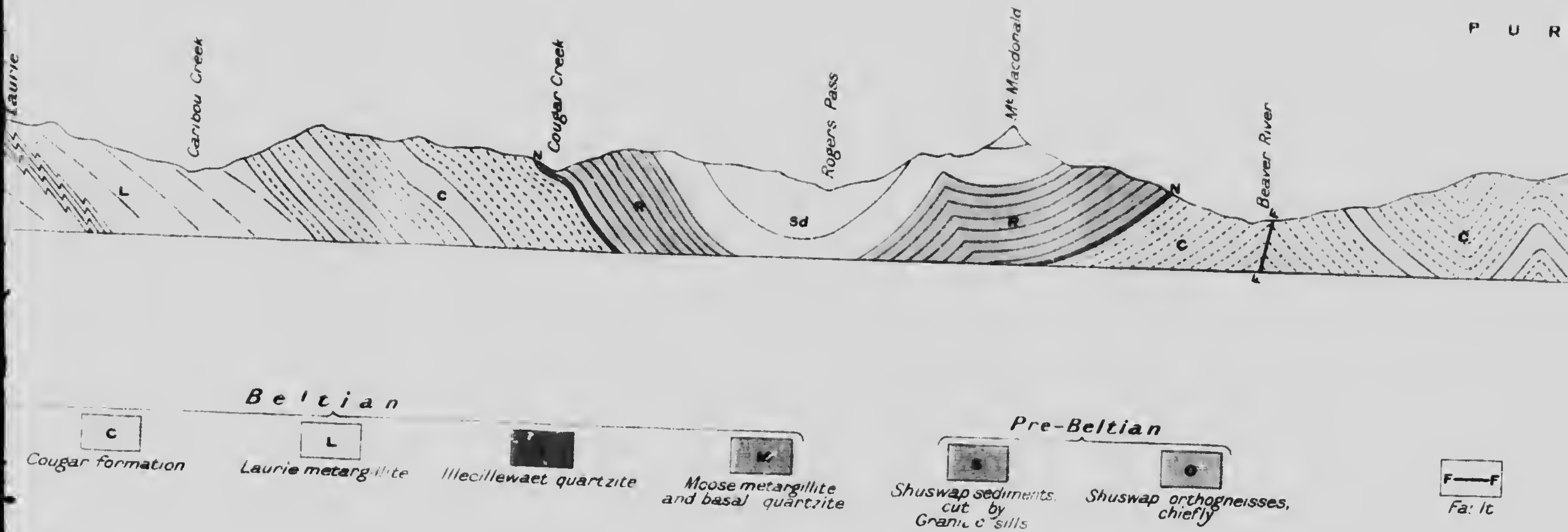


Structure Section of the Selkirk and Purcell Mountains from M

Horizontal and vertical scale



f the **Selkirk** and **Purcell Mountains** from **Moberly Peak** to **Revelstoke**

Horizontal and Vertical scale

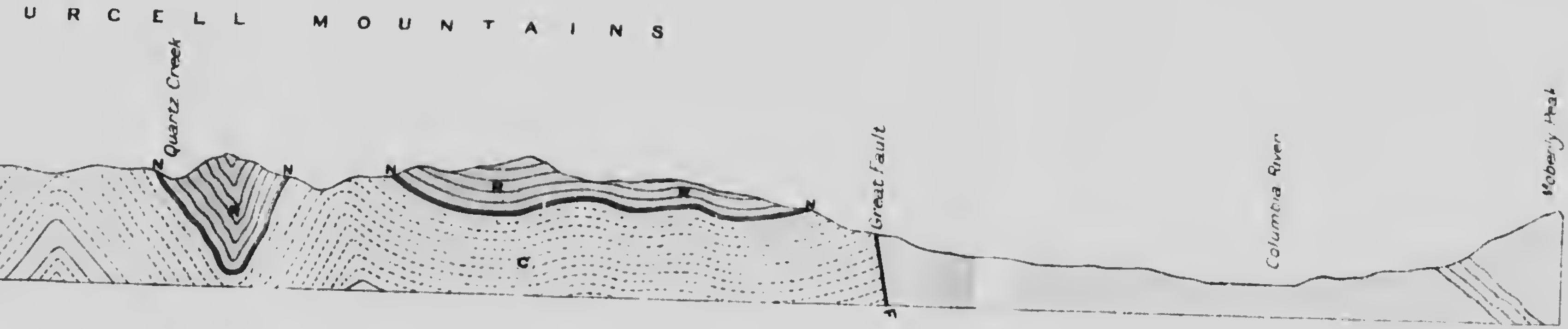
Miles

2 3 4 6 7 8 9 10

Kilometre

5 10 15

C I.


URCELL MOUNTAINS
Quartz Creek
Great Fault
Columbia River
Moberly Peak
C.